WATER WORKS & SEWERAGE

A GILLETTE ABC PUBLICATION

Vol. 86, No. 5 MAY, 1939 L. H. Enslow Editor

Valve Control

Visible Rota Meter

Automatically Safe

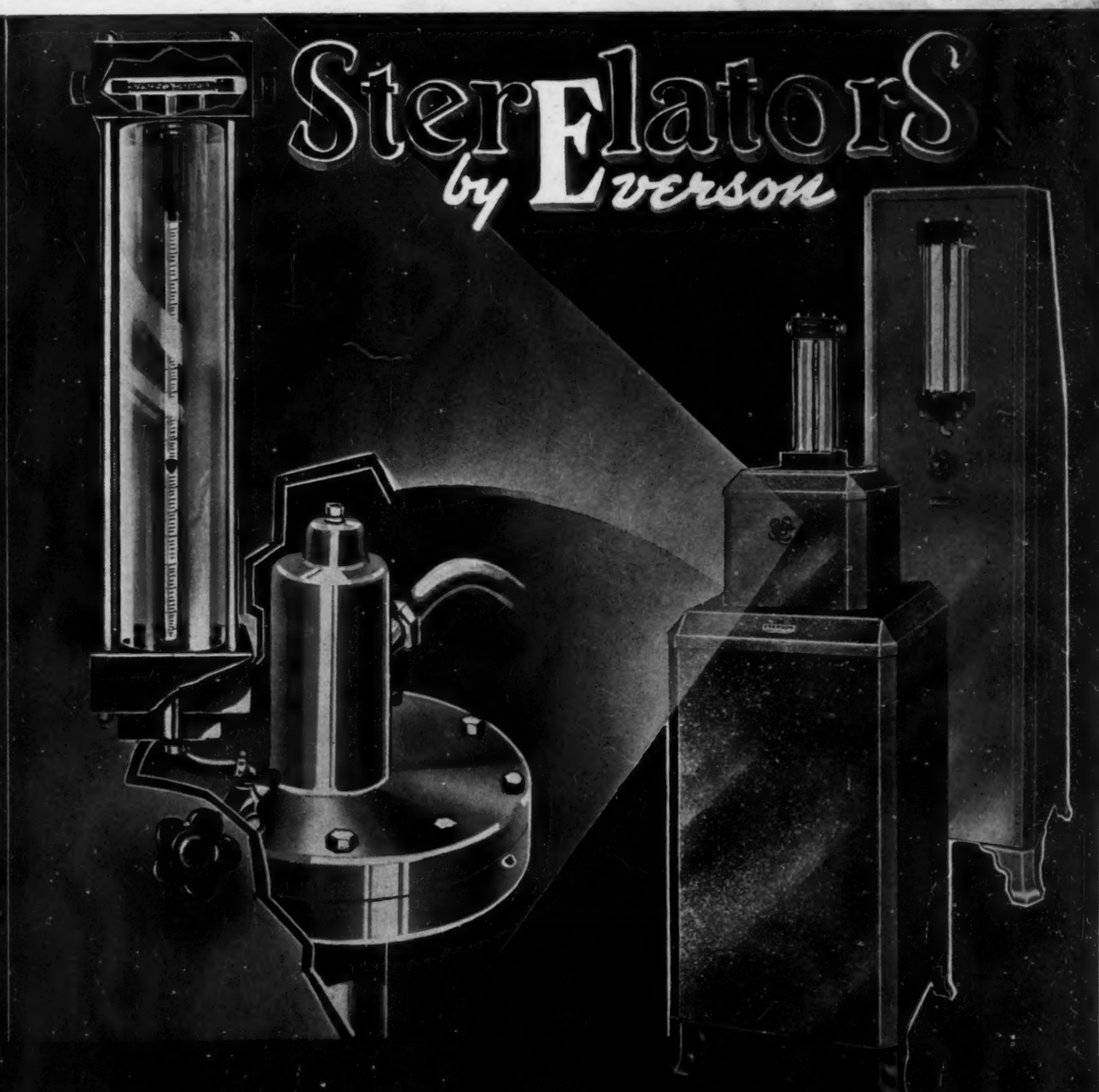
Automatic Gas Shut-off

Automatic Synchronizing with Pump

Operates under 20 water gauge vacuum.

Far wider metering range in any capacity.

Multiplex Feed to 4 or more points from a single SterElator.



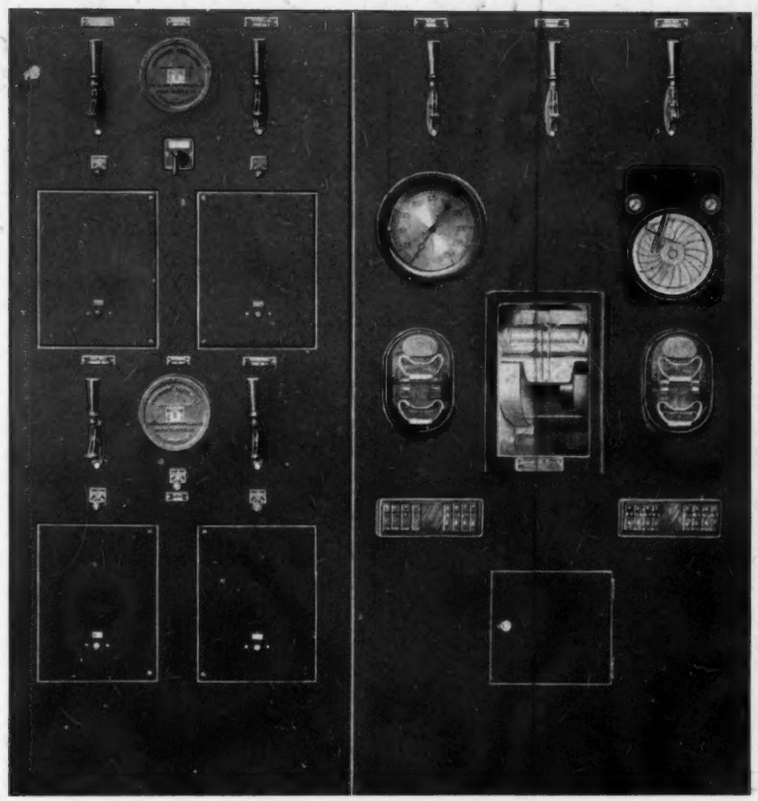
LOOK through to the future a century hence, you men who are planning and constructing cast iron underground mains, and what can you be sure of! Just this: cities may be destroyed—mains abandoned or relocated—but there will be a *hundred years or more of useful life* in every length of cast iron pipe, whether it be pit cast or centrifugally cast by the Super-de Lavaud chill-free process.

U.S. cast iron PIPE

Centrifugally or pit cast for water, gas, sewerage, drainage and industrial service.

U. S. PIPE & FOUNDRY CO.
General Offices: Burlington, N. J.
Foundries and Sales Offices throughout the U. S.

2-20 HP, & 2-30 HP, 220 VOLT, 3 PHASE, 60 CYCLE MOTORS CONTROLLED BY CLARK-SUNDH DEAD FRONT PANEL



¶ One Panel of this Dead Front Steel Switch Board houses 2-20 HP and 2-30 HP, 220 Volt, 3 phase, 60 cycle, Across-the-Line type Motor Starters, equipped with Manual Testing Switch, independent of the Automatic operation.

¶ The 2-30 HP Motors operate a deep Well Centrifugal and a Boost Pump, both Pilot Switch operated by Float Switch Control.

¶ The 2-20 HP Centrifugal Booster Pumps are operated by Pressure Control with transfer facilities for interchanging the 2 Bourdon Tube Type Regulators with the 2 motor starters.

¶ The other panel houses the incoming line, metering, recording, and lighting distribution section.

¶ All Knife Switches and Transfer Switches are externally operated without live parts on front of board, providing operator protection as well as motor protection.

¶ Typical of the neatness and efficiency of Clark-Sundh Control apparatus, this Dead-Front Steel Switch Board effectually helps keep a Mid-West city Water Works operating efficiently.

¶ For Water Works and Sewage Disposal Plant electrical control, please contact our nearest office.

OFFICES IN PRINCIPAL CITIES

THE CLARK CONTROLLER CO.

1146 EAST 152ND ST. CLEVELAND, OHIO

WATER WORKS AND SEWERAGE, May, 1939. Volume 86. Number 5. Published monthly at 330 South Wells Street, Chicago, Ill., by the Gillette Publishing Company. Per copy, 50c. Subscription rate, United States and Canada, $2.00 per year; Foreign, $3.00 per year. Copyright, 1939. Entered as Second Class Matter, June 2, 1931, at the Post Office at Chicago, Ill., under Act of March 3, 1879. .

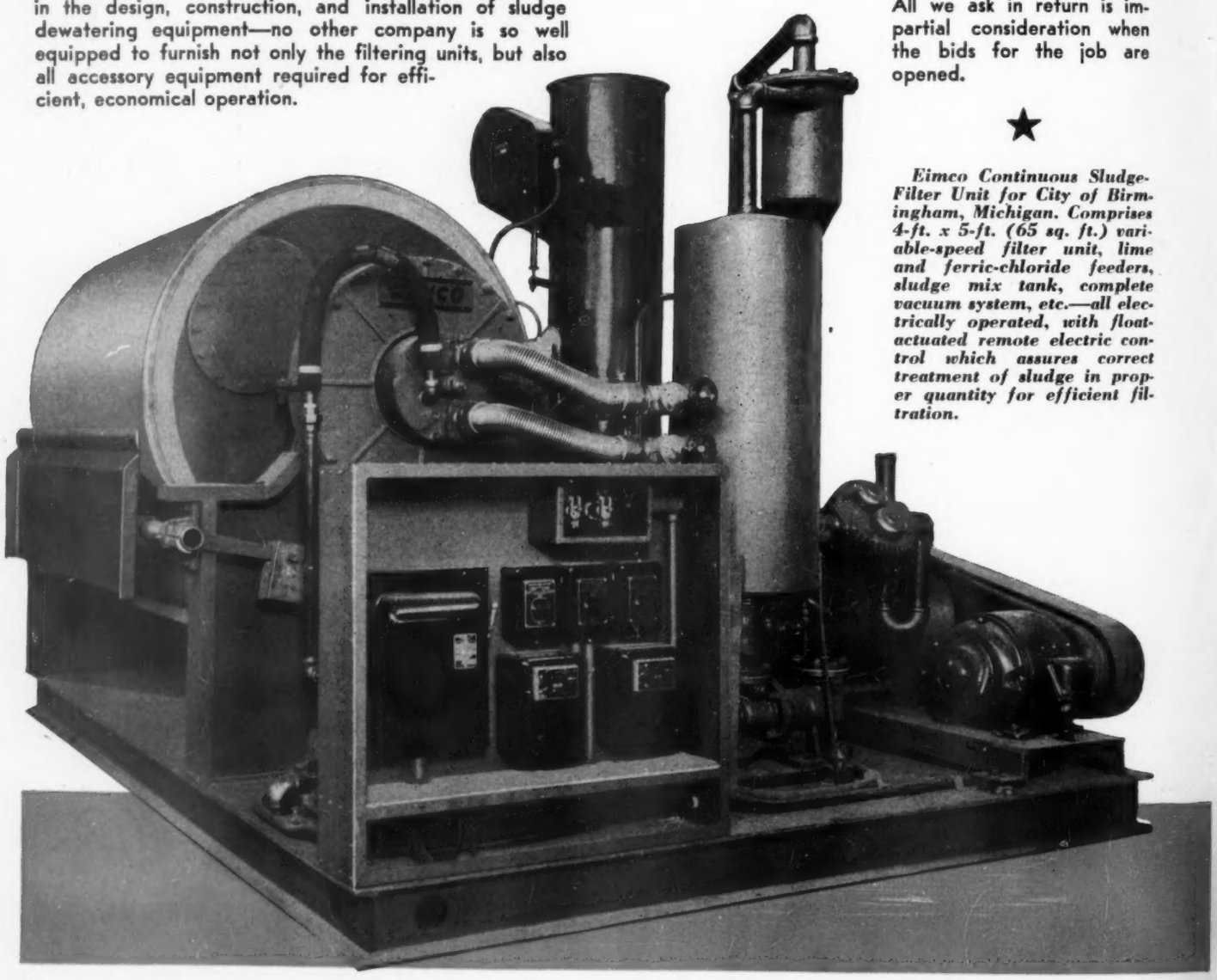
EIMCO *Continuous Sewage Filters*

SOLVE SLUDGE DEWATERING PROBLEMS . . . LEAD THE WAY IN *Unit-Built* DESIGN

THE present rapid trend toward the use of Eimco Continuous-Vacuum Filters for dewatering sludge in modern sewage disposal plants is based on sound reasoning. Leading consulting engineers in the sanitation field realize the necessity for rugged, unit-built equipment—appreciate the effective co-operation provided by Eimco's highly experienced sewage-filtration engineers. No other filter manufacturing company, anywhere, can provide such complete service in the design, construction, and installation of sludge dewatering equipment—no other company is so well equipped to furnish not only the filtering units, but also all accessory equipment required for efficient, economical operation.

Eimco's Sewage-Disposal Engineering Staff is headed by F. E. Kurz and Paul Richter who are located in our Chicago office (333 N. Michigan Ave.) and are available for consultation on short notice anywhere east of the Rocky Mountains. Designs, specifications and estimates for improved unit-built installations to meet any given requirement or condition are furnished to responsible engineering or contracting organizations without charge or obligation of any kind. All we ask in return is impartial consideration when the bids for the job are opened.

★



Eimco Continuous Sludge-Filter Unit for City of Birmingham, Michigan. Comprises 4-ft. x 5-ft. (65 sq. ft.) variable-speed filter unit, lime and ferric-chloride feeders, sludge mix tank, complete vacuum system, etc.—all electrically operated, with float-actuated remote electric control which assures correct treatment of sludge in proper quantity for efficient filtration.

BACK of Eimco's superior engineering service is the largest and most complete manufacturing plant possessed by any manufacturer of continuous-vacuum filters. For more than a quarter of a century the various divisions of this organization have been furnishing iron and steel castings, structural steel and plate work, steel forgings, machine tool work and special machinery of all kinds to leading mining, railroad and industrial organizations throughout the United States and other countries. No job is to large—no specification too rigid for Eimco to handle promptly and efficiently.

Applied to the manufacture of filtration and dewatering equipment these complete facilities assure higher standards of quality and more dependable deliveries than would otherwise be possible. Complete control of every step in production from drafting room to finished product enables us to eliminate many difficulties and delays which are unavoidable when work must be "farmed out" to other plants. Another advantage, of even greater importance to most buyers, is the reduction in unit overhead costs achieved through the large volume of work constantly passing through our shops. Savings thus secured are amplified by the use of modern money-saving equipment not available in smaller plants, and largely passed on to purchasers.

★

Recent Awards to EIMCO for Complete Sewage Sludge Dewatering Installations . . . include:

Kings Park, Long Island, N. Y.

Birmingham, Michigan

Anderson, Indiana

Sterling, Illinois

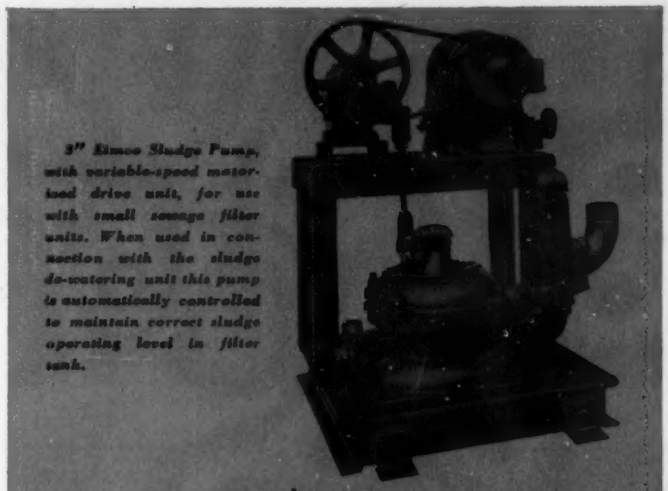
Stevens Point, Wisconsin

Peru, Illinois

Marshalltown, Iowa

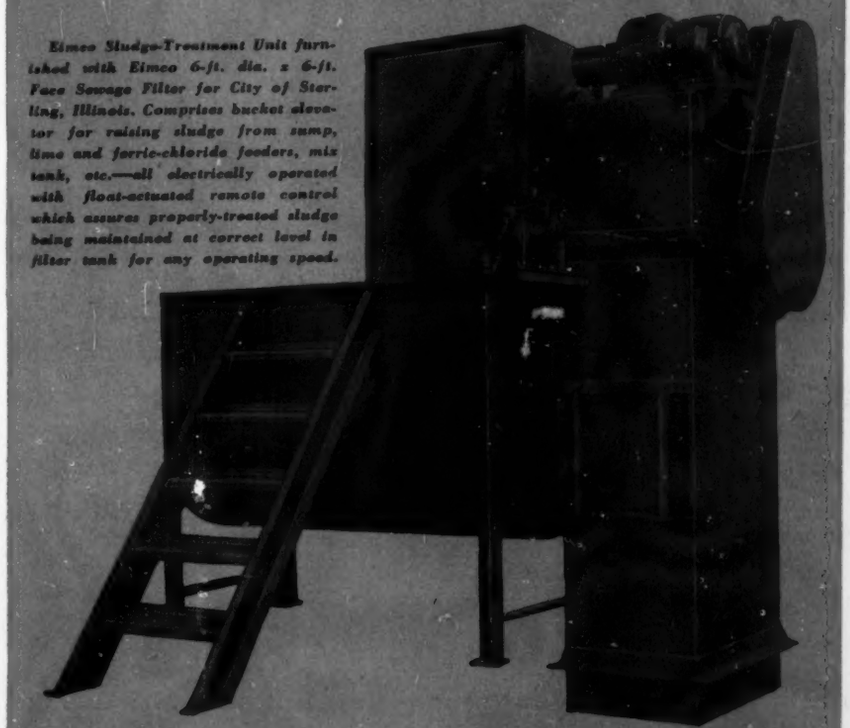
Piqua, Ohio

Details regarding any of these modern Eimco unit-built installations, together with a summary of the requirements to be considered in each case, can be secured on request from our Chicago office. If you are planning a modern sewage disposal plant write today for this valuable information—it may easily help you to achieve important savings in time and money.



3" Eimco Sludge Pump, with variable-speed motorized drive unit, for use with small sewage filter units. When used in connection with the sludge de-watering unit this pump is automatically controlled to maintain correct sludge operating level in filter tank.

Eimco Unit-Built Cake Conveyor—equipped with motorized power unit, and totally enclosed roller-chain drive to the head-shaft. Clean cake discharge, with minimum wear on belt, is assured by use of a bevel-edge scraper with adjustable counter-weight which can be set to maintain correct belt contact for any type or consistency of cake.



Eimco Sludge-Treatment Unit furnished with Eimco 6-ft. dia. x 6-ft. Face Sewage Filter for City of Sterling, Illinois. Comprises bucket elevator for raising sludge from sump, lime and ferric-chloride feeders, mix tank, etc.—all electrically operated with float-actuated remote control which assures properly-treated sludge being maintained at correct level in filter tank for any operating speed.

THE EIMCO CORPORATION

SALT LAKE CITY, UTAH, U.S.A.

NEW YORK EL PASO CHICAGO SACRAMENTO

MATHIESON *HTH* FOR SAFE BEACHES

Says George R. Young, Village Manager, Village of Glencoe, Illinois: March 7, 1939

"You will be interested in our successful use of HTH on our Lake Michigan Beach . . . Two problems were involved: foot infections from the bacteria in the sand, and insects . . . HTH was tried, using a 2% solution. We were able with this solution sprayed on the sand to reduce the fly egg count from 800 per square inch to almost none. We eliminated bacteria and foot infection completely, so far as we were able to determine. We feel that the added satisfaction and confidence inspired in our Glencoe residents who use the beach was well worth while . . . In the past ten years we have enjoyed excellent service from your company."

• *Municipal Bathing Beach Glencoe, Illinois*

• *Filtration Plant Glencoe, Illinois Waterworks*

MATHIESON CHLORINE FOR SAFE DRINKING WATER

HTH is a dry, free-flowing chlorine carrier. 70% of its weight is chlorine available for killing bacteria and destroying odors and other objectionable contamination. Its germ-killing power is released rapidly, uniformly—requires no bulky equipment, no specially expert or experienced operator. Best of all HTH really does the job.

Glencoe is only one of the many villages, towns and great cities throughout the country that have found in HTH and Mathieson Chlorine the ideal solution of the problem of water purification, sewage treatment, beach and pool sanitation.

Mathieson Chlorine means a pure, dependable product — safe, trouble-free containers and valves — prompt delivery service. In addition you have available the full cooperation of Mathieson's expert technical staff.

THE Mathieson Alkali Works (INC)

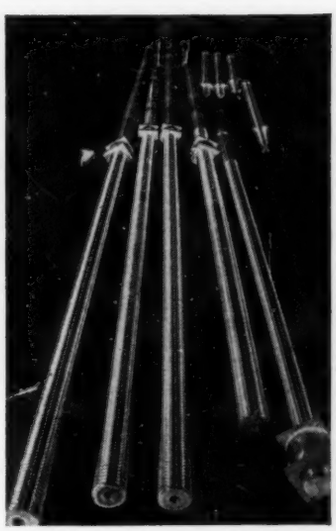
60 EAST 42ND STREET, NEW YORK, N. Y.

LIQUID CHLORINE . . . HTH . . . SODA ASH . . . CAUSTIC SODA . . . BLEACHING POWDER . . . BICARBONATE OF SODA . . . AMMONIA, ANHYDROUS and AQUA . . . PH-PLUS (FUSED ALKALI) . . . DRY ICE . . . LIQUID CARBON DIOXIDE . . . GYPSUM PRODUCTS

KOPPERS

DOES A BETTER JOB FOR YOU

1. KOPPERS BUILT-UP ROOFS of coal tar pitch and tar saturated felt resist water and sun. Engineers may safely recommend them for water-cooled and spray pond roofs used in conjunction with air conditioning systems, thereby preventing an overload of the city's supply and sewage facilities. "Koppers Specifications," which gives construction details, will be mailed on request.



3. KOPPERS D-H-S BRONZE STEMS resist torsional stress, friction and corrosion. In many applications, they cost less than substitute materials and in *all* applications they provide a certain and inexpensive means of assuring dependable stem performance.

4. KOPPERS TAR BASE PAINTS resist the action of acids, alkalies and hydrogen sulfide. They are effective and economical for protecting metal surfaces—buildings, structural work, machinery, pipe lines, and steel work.

2. KOPPERS MEMBRANE GASPROOFING AND WATERPROOFING are used to prevent the escape of gas from sludge digestion tanks. Filter beds, clear wells and conduits are made waterproof with Koppers Membrane Waterproofing.

KOPPERS *products*

5. Fire Plugs **6. Tarmac for Paving** **7. Floor Stands** **8. Valves**
9. Fast's Self-aligning Couplings **10. American Hammered Piston Rings**
11. Pressure-treated Timber **12. Engineering and Construction Work**

KOPPERS COMPANY · PITTSBURGH

Liquid Chlorine ★ Perchloron

★ ★ ★

Two notable products now work together to help you safeguard the water supply of your community. One is liquid chlorine so pure that it materially reduces operating difficulties. The second is Perchloron, which acts as a second line of defense in time of emergency. Both together give you a *System of Safety* that is almost unfailing.

The liquid chlorine supplied by this Company is a great advance in purity, for it is virtually free from organic impurities. This is made possible by a new purifying process developed by Pennsylvania Salt which reduces trouble-making substances to so low a point that even their cumulative effect over long periods of operation can scarcely be traced.

As a further safeguard, a new means of manufacturing control was developed—an improved analytical method of evaluating chlorine as to troublesome impurities. Every available means has been used to provide you with a product that minimizes the formation of "taffy". You are certain to find this a superior liquid chlorine.

If ever your chlorine supply fails . . .

If normal conditions were the only ones possible, you would never need to prepare for emergencies. But a hurricane, a blizzard, a flood, or a tremendous fire, may tie up transportation and deprive you of normal supplies of liquid chlorine. That is when you will appreciate Perchloron.

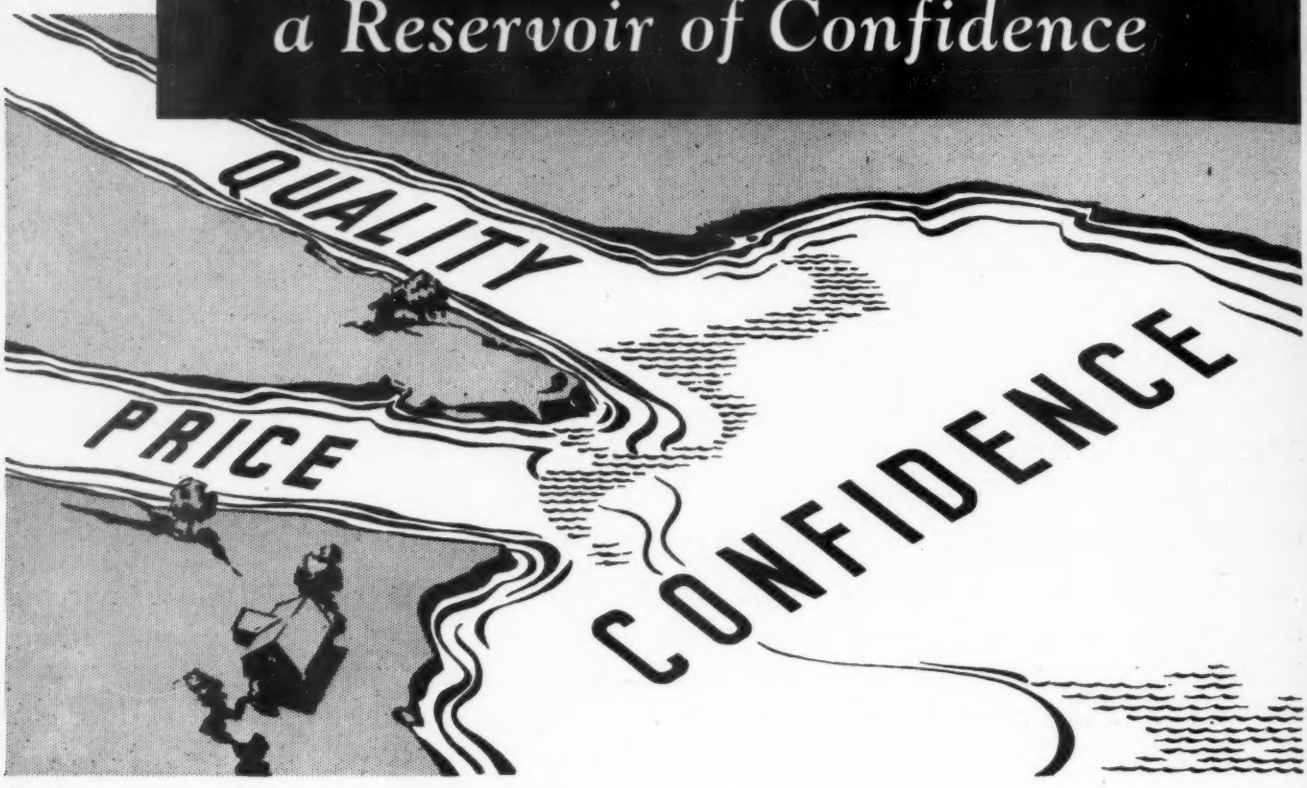
With an available chlorine content of over 70%, Perchloron is a dependable source of chlorine in emergency. It is stable, concentrated, uniform. Dissolves readily in water. Packed 12 handy cans to the case, each can with punch-and-pry-up top. Also in 75 lb. drums.

It is convenient and economical, not only for emergency chlorination, but for sterilizing new mains, for clear wells and filters, and for swimming pool sanitation. Write for free booklet today. Pennsylvania Salt Manufacturing Co., Widener Bldg., Philadelphia, Pa.—New York • Chicago • St. Louis • Pittsburgh • Tacoma • Wyandotte.

PENNSYLVANIA SALT
MANUFACTURING COMPANY
Chemicals

HYDRODARCO*

Quality and Price form a Reservoir of Confidence



"A reservoir of confidence"—Darco has won the confidence of users of activated carbons ***in field after field!***

Here are just a few of the fields in which Darco is pre-eminent. Sugar refiners, for example, expect and get higher yields of pure, white crystals by processing the "raws" with Darco. Men in the photographic supply business use Darco to purify the chemicals for developing film negatives—and get better photographs. Dry cleaners use Darco to purify and sweeten the dry-cleaning solvent—and get better work for lower costs.

And—men throughout the waterworks field have this same feeling of confidence in Hydrodarco*—the activated carbon specially made by Darco for removing tastes and odors from water supplies.

Hydrodarco quality meets any test, any time—with convincing results. Yet Hydrodarco's top quality costs not one cent more. By any comparison, Hydrodarco prices are ***lowest!***

Write today for a free sample of Hydrodarco. Be ready to save money by ordering Hydrodarco the next time you need activated carbon.

* Reg. U. S. Pat. Off.

DARCO

DARCO CORPORATION

60 East 42nd Street, New York, N. Y.

Distributing Points

•

NEW YORK - - BUFFALO
CINCINNATI - - CHICAGO
ST. LOUIS - KANSAS CITY
• SAN FRANCISCO •
• LOS ANGELES •
• MARSHALL, TEXAS •
• MONTREAL, CANADA •

You are Cordially Invited to Visit this Plant while at Atlantic City

Our 80-acre plant and foundry at Florence, N. J., near Atlantic City

Would you like to gaze straight into gigantic molds as they whirl, while white-hot iron rushes in and spins itself into 20-foot lengths of 20-inch pipe before your eyes?

Would you like to see 40-foot lathes machine "flasks" as big as gun barrels? Watch giant planers capable of trimming fifty-ton castings like cheese? Mechanics may be assembling three-story-high hydraulic presses, some of the largest machines built today.

Would you like to see molds filled, tamped, joggled and upset for Mathews Hydrants? Or watch iron and bronze poured, machined and assembled into the standard hydrant of America? In a word, would you like to inspect, under expert guidance, one of the biggest and most important foundries which serves the water works industry?

We cordially mvite you to do so. Just speak to any of our representatives at the R. D. Wood booth during the convention. We'll arrange for comfortable automobile transportation, good company, able guides, and a quick return, all scheduled to suit your convenience.

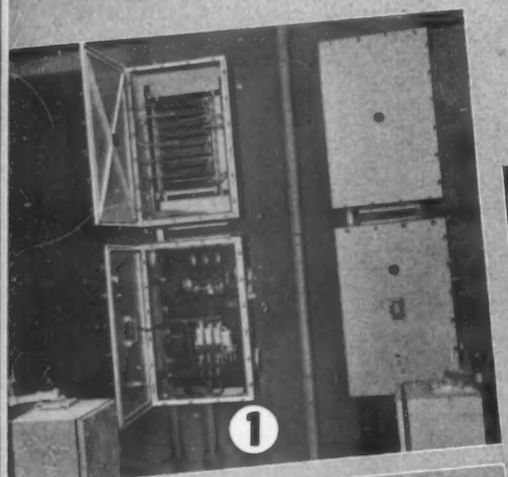
The invitation includes your wife. Will you come?

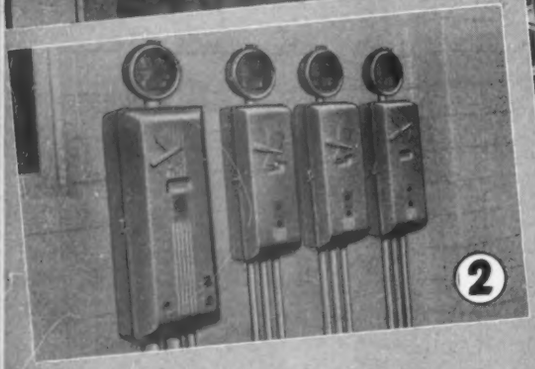
Again they choose
FOR TALLMANS ISLAND

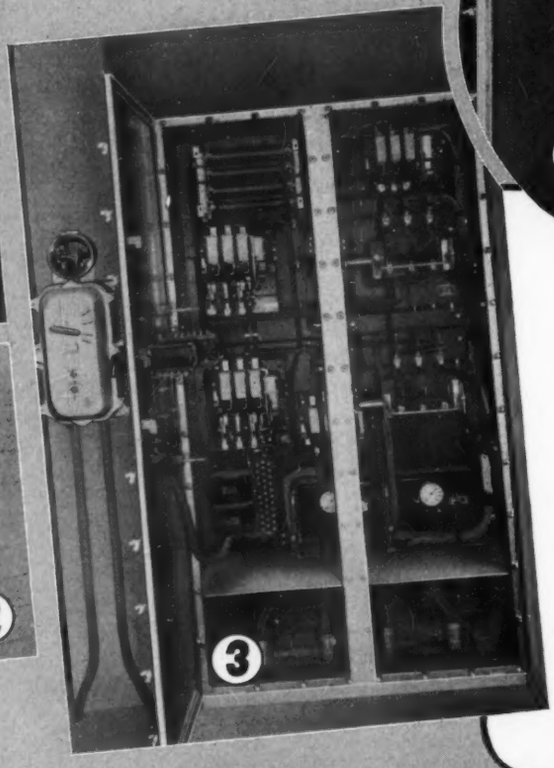
New testimony on the quality and dependability of Westinghouse electrical equipment for sanitation projects is given by its selection for the exterior lighting and practically all controls in the $3,830,000 Tallmans Island Plant.

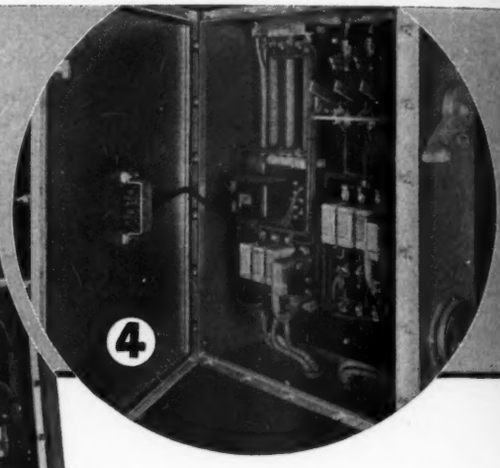
This 40-80 million g. p. d. plant serving the New York World's Fair area is the latest notable addition to the list of 48 out of 94 U. S. cities of over 100,000 population employing Westinghouse electrical apparatus in sewage disposal plants or waterworks. In all of these projects, as well as in Tallmans Island Plant, close co-operation between sanitation engineers and Westinghouse has resulted in electrical equipment tailored to the job.

Our representative will place these engineering facilities at your disposal. Westinghouse Electric & Manufacturing Co., E. Pittsburgh, Pa.









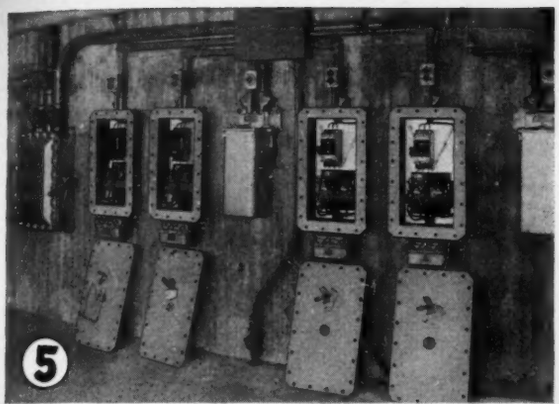
1 Magnetic primary panel for 25 hp wound rotor motor driving sewage pump, with built-in push button, interlocked door, externally operated safety switch. Water and dust-tight cabinet. Upper case encloses secondary speed regulating resistors. At bottom, right and left, are manually operated drum controllers.

2 Combination Linestarters in sheet metal drip-proof cabinet, with aluminum and cadmium finish, for resistance to

Westinghouse

WESTINGHOUSE

SEWAGE TREATMENT PLANT



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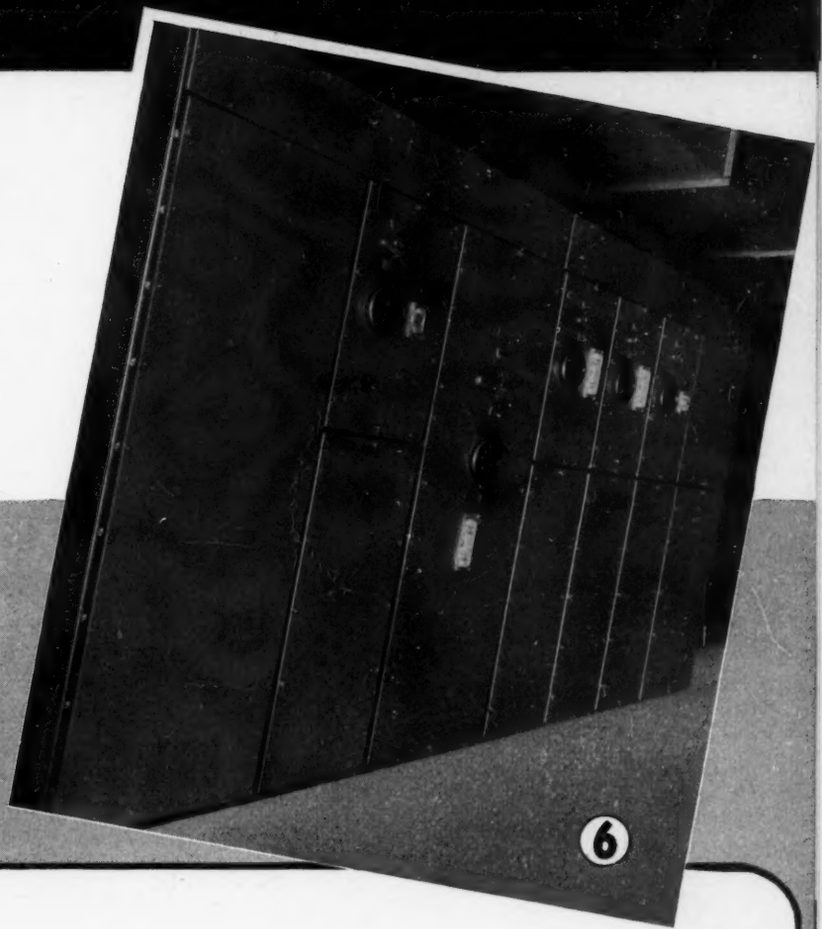

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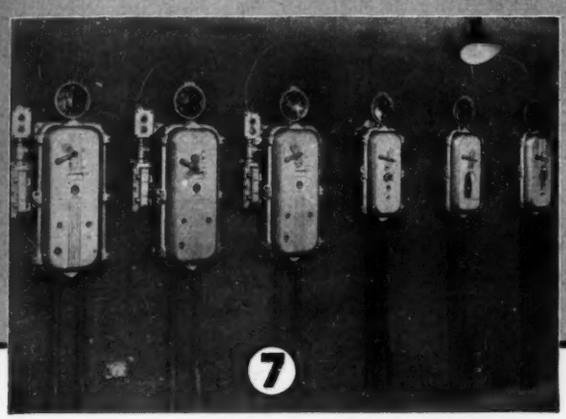


7

moisture and gases, operate motors for MG sets. Instrument sockets also provided.

3 Duplex controller for air compressors comprises two complete resistor type reduced voltage starters with built-in push-button station; selector drum switches for transferring starter from pressure regulating control to push-button control. Unit includes also a selector drum switch for interchanging pressure regulators.

4 Resistor type reduced voltage starter, in dust-tight, water-tight case for circulating water pump control. Built-in push button and externally operated safety switch interlocked with door. Testing sockets included.

5 Four explosion-proof combination Linestarters with explosion-proof, push-button stations control the 5 hp 2-speed sludge pump motors. Oil immersed combination Linestarters (center and extreme right) for 5 hp slurry pump motor, and 1½ hp lime dry feed motors.

6 One of the Distribution Centers.

7 The three special combination Linestarters (right) control sludge collector motors. Those on the left are for 5 hp 2-speed sludge pump motors. Cast-iron, water-tight cabinet has special cadmium and aluminum finish. Notice sockets for test jacks and industrial analyzers.

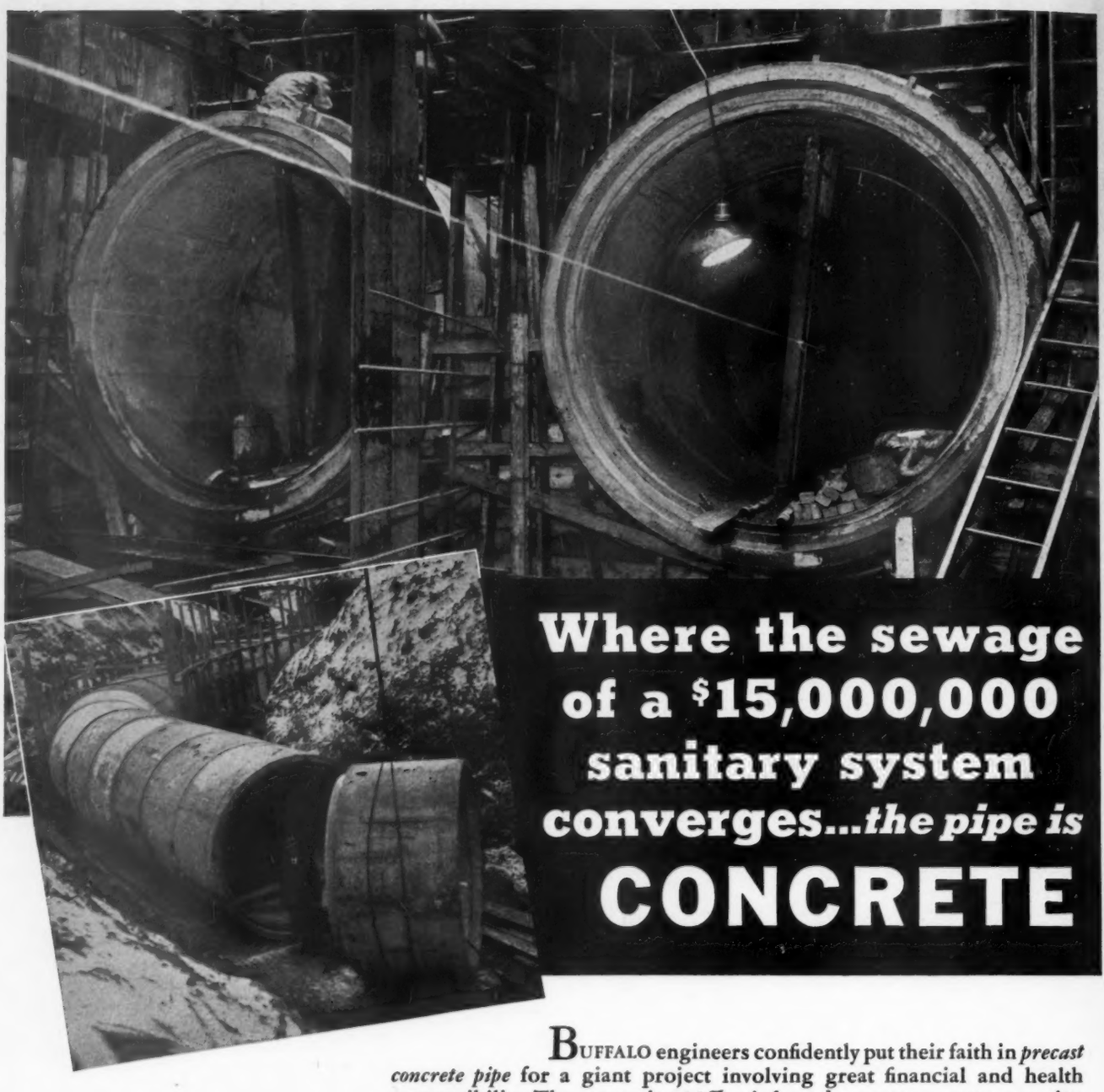
J-94039

ELECTRICAL PARTNER

OF THE SANITATION ENGINEER

W

WESTINGHOUSE ELECTRIC



Where the sewage of a $15,000,000 sanitary system converges...*the pipe is* CONCRETE

Above—Twin 96-in. reinforced concrete pipe in West cofferdam on Bird Island, near the disposal plant. These lines, together with similar lines of 96-in. subaqueous pipe from the mainland, carry all of Buffalo's sanitary sewage under the harbor.

●

Below—96-in. by 5-ft. radial sections, at the storm water overflow outlet. Curves through 77 degrees at each end of line required 12 pieces of specially fabricated radius pipe. Greeley and Hansen, consulting engineers, Chicago, are engineers for the Buffalo Sewer Authority, with C. R. Velzy as resident engineer.

BUFFALO engineers confidently put their faith in *precast concrete pipe* for a giant project involving great financial and health responsibility. The system is 100% reinforced concrete or concrete pipe from 24-in. to 96-in. Open trench, tunnel and subaqueous installation.

Built by the Buffalo Sewer Authority, with PWA grant and loan, this project is to relieve the Buffalo River and the lake harbor from excessive pollution, and to reduce pollution and bacterial content of the Niagara River to lessen the load on water treatment plants downstream.

Methods for gaining these objectives include: (1) diversion of sewage from the river and harbor by intercepting the dry weather flow and a portion of the early storm flows; (2) treatment to remove suspended and floating solids and to effect a satisfactory bacterial removal; and (3) proper dispersion of the plant effluent into the Niagara River.

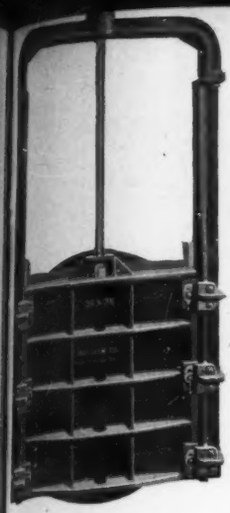
Compared with sewage from other cities, that of Buffalo may be characterized as rather strong, and in volume, somewhat greater than the average. It is influenced by industrial waste.

Where Millions are at Stake Sewers are Built of Concrete

As in other cities, concrete pipe was chosen for Buffalo because it has demonstrated its adaptability, safety and economy for a wide range of sewer conditions and requirements. It minimizes infiltration and leakage; resists corrosion; is strong and durable, and serves with little maintenance. Write for literature on concrete pipe or reinforced concrete sewer construction.

PORTLAND CEMENT ASSOCIATION • **Dept. A5-29, 33 W. Grand Ave., Chicago, Ill.**

YOUR SPECIFICATIONS ACCURATELY MET



Circular Opening
Non-Rising Stem
Sluice Gate

Rectangular Opening
Rising Stem Sluice Gate

Hand Operated
Floor Stand

Electrically
Operated
Floor Stand

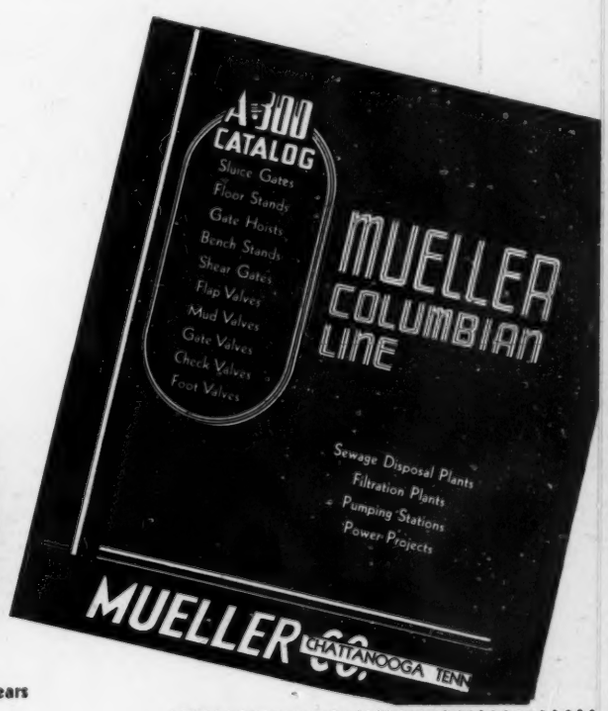
Most specifications for Water Controlling Equipment can be met by Mueller Co. with their regular line of Sluice Gates, Gate Valves, Operating Controls (Manual, Hydraulic or Electric), Mud Valves, Flap Valves etc., and Mueller Co. also has the facilities and ability to produce any special type of equipment accurately and to specification.

All equipment passes rigid inspection and is thoroughly tested under pressure before shipment. This means easy installation and operation and is your assurance that the equipment will meet the requirements under actual service conditions. Consult your Mueller A-300 Catalog before specifying your equipment. If you haven't your personal copy, use the convenient coupon today.

Bronze Mounted
Flap Valve

Non-Rising Stem
Mud Valve

48" Gate Valve with
8" by-pass and bevel gears
without grease case



MUELLER CO.

CHATTANOOGA, TENN.

Dept. M.
Mueller Co.,
Chattanooga, Tenn.

Gentlemen:

Please send me a copy of your A-300 Catalog showing your complete line of Water Controlling Equipment.

Name_____

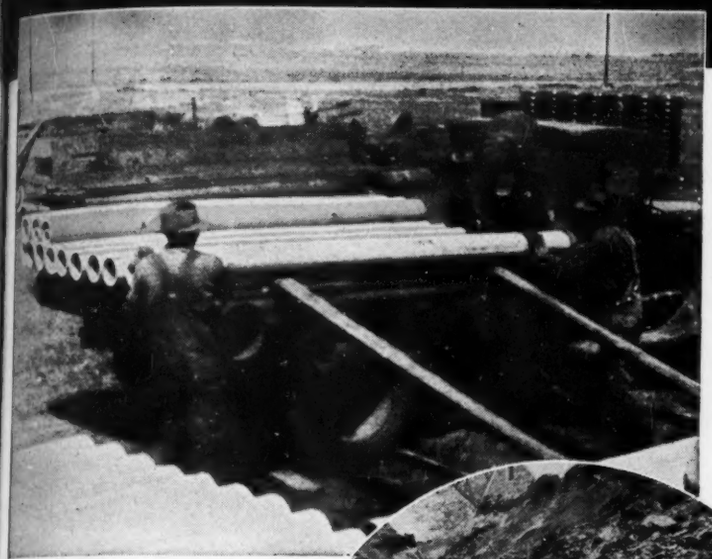
Address_____

Mail Coupon TODAY!

ELECTRO BLEACHING GAS COMPANY · Main Office: 60 EAST 42nd STREET, NEW YORK, N.Y. · Plant: NIAGARA FALLS, N.Y.
UNIFORM
EBG
Liquid Chlorine

1st FEATURE OF AN EFFICIENT, LOW-COST WATER SYSTEM

LOW INSTALLATION COSTS . . .



UNUSUALLY LIGHT IN WEIGHT, Transite permits the use of smaller trucks in carrying the pipe to the job. More linear feet can be carried per truckload—and, at the trench, Transite is easily handled by small crews without costly mechanical equipment.

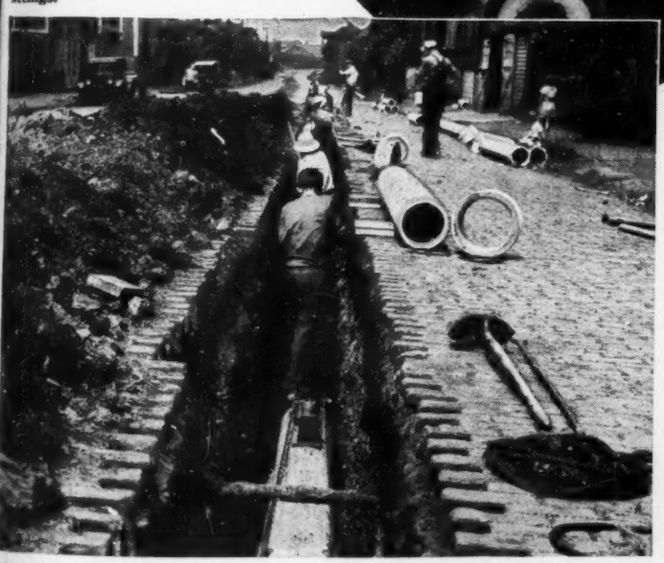
• • •

TRENCHING COSTS are held to a minimum, for Simplex Couplings do away with the need for large bell holes at joints. And the flexibility of these bottle-tight couplings permits laying straight lengths of Transite around curves without special fittings.

LOOKING for practical ways to cut water-line costs? Begin right at installation. Check the advantages of J-M Transite Pipe—you'll see how its light weight makes transportation to the job easy and economical—how its long lengths and simple assembly method speed up installation, reduce laying expense. These two features alone mean sizable reductions in the cost of your entire system.

And that's only the beginning of Transite's many savings. Made of asbestos and cement, Transite Pipe can never rust or tuberculate—its high flow coefficient of C-140 keeps pumping costs permanently low. And, because this modern, durable pipe is immune to electrolysis and highly resistant to soil corrosion, maintenance costs are practically zero.

Yet, with all these advantages, Transite Pressure Pipe costs no more than ordinary pipe. For details, write for brochure TR-11A. And if you are interested in efficient, low-cost sewerage systems, ask for the Transite Sewer Pipe Brochure, TR-21A. Address Johns-Manville, 22 East 40th Street, New York, N. Y.



RAPIDLY INSTALLED—Laying crews can install Transite Pipe as fast as the trench is opened. Simplex Couplings are assembled cold, require no costly heating equipment on the job. Skilled pipe fitters are unnecessary—ordinary crews can assemble Transite rapidly and efficiently with a simple chain puller.

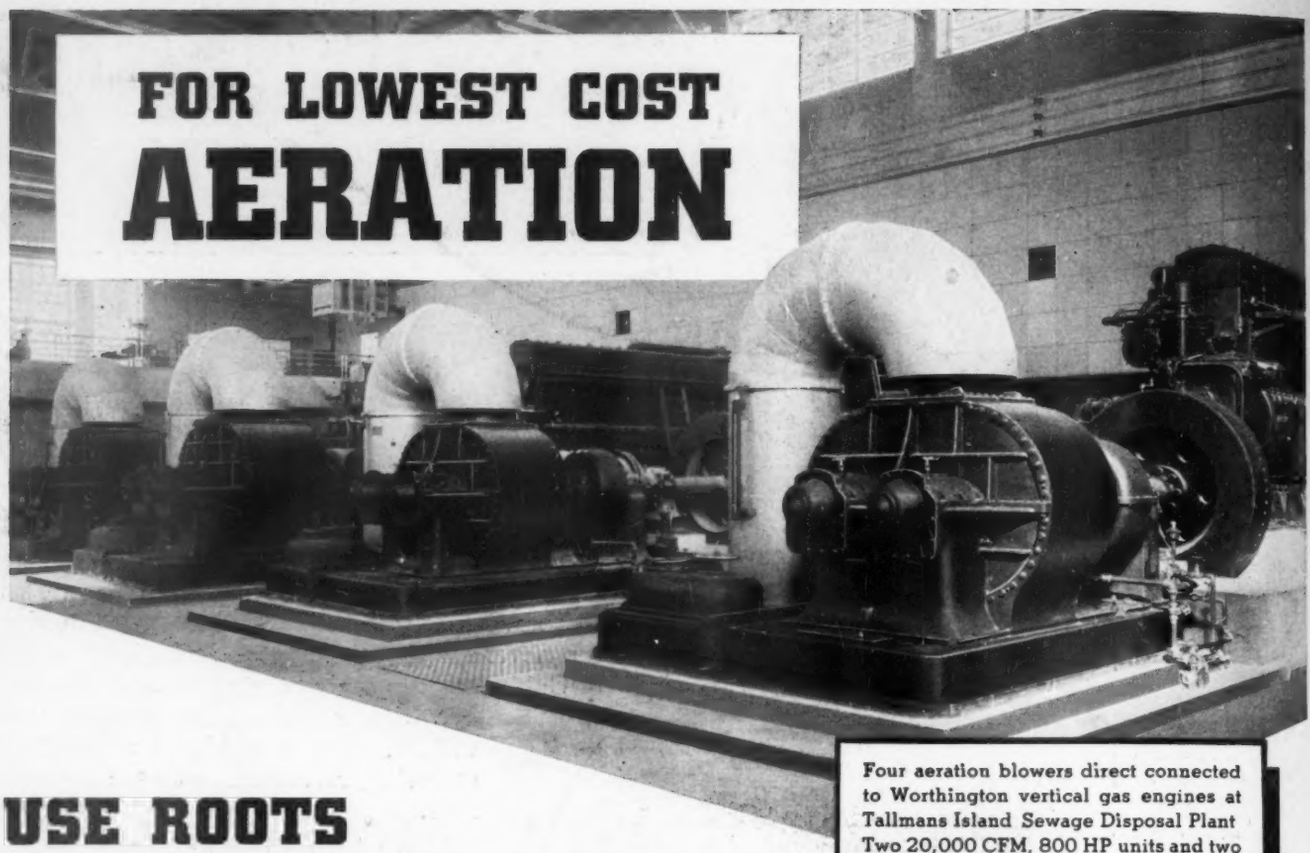
FITTINGS AND SERVICE CONNECTIONS are simply and quickly made in Transite Pipe with standard tapping tools. No special operations are required. Mains are easily tapped while under pressure. And the resulting connections are strong, permanent and water-tight . . . provide maximum protection against leakage.

JM PRODUCTS

Johns-Manville TRANSITE PIPE AN ASBESTOS PRODUCT

THE MODERN MATERIAL FOR SEWER AND WATER LINES

FOR LOWEST COST AERATION



Four aeration blowers direct connected to Worthington vertical gas engines at Tallmans Island Sewage Disposal Plant Two 20,000 CFM, 800 HP units and two 10,000 CFM, 400 HP units, total capacity 60,000 CFM at 8 pounds gauge pressure, 2400 HP

USE ROOTS CONNERSVILLE BLOWERS

SELECTION of the activated sludge type of treatment for the new Tallmans Island Sewage Disposal Plant, located adjacent to the site of the New York World's Fair, insures the highest degree of treatment for handling the enormous World's Fair transient population and effectively prevents pollution of the waters of Flushing Bay.

SELECTION of Roots-Connersville Positive Displacement Blowers direct connected to gas engines, using gas obtained as a by-product from the digestion of sewage sludge for power, insures lowest cost of aeration at any plant. Roots-Connersville Positive Displacement Blowers show higher efficiencies than any other type. Direct gas engine drive gives easy control of variable volumes and approximately 25% more air than where the gas available is used to develop electric power for motor driven blowers.

Roots CONNERSVILLE BLOWER CORPORATION

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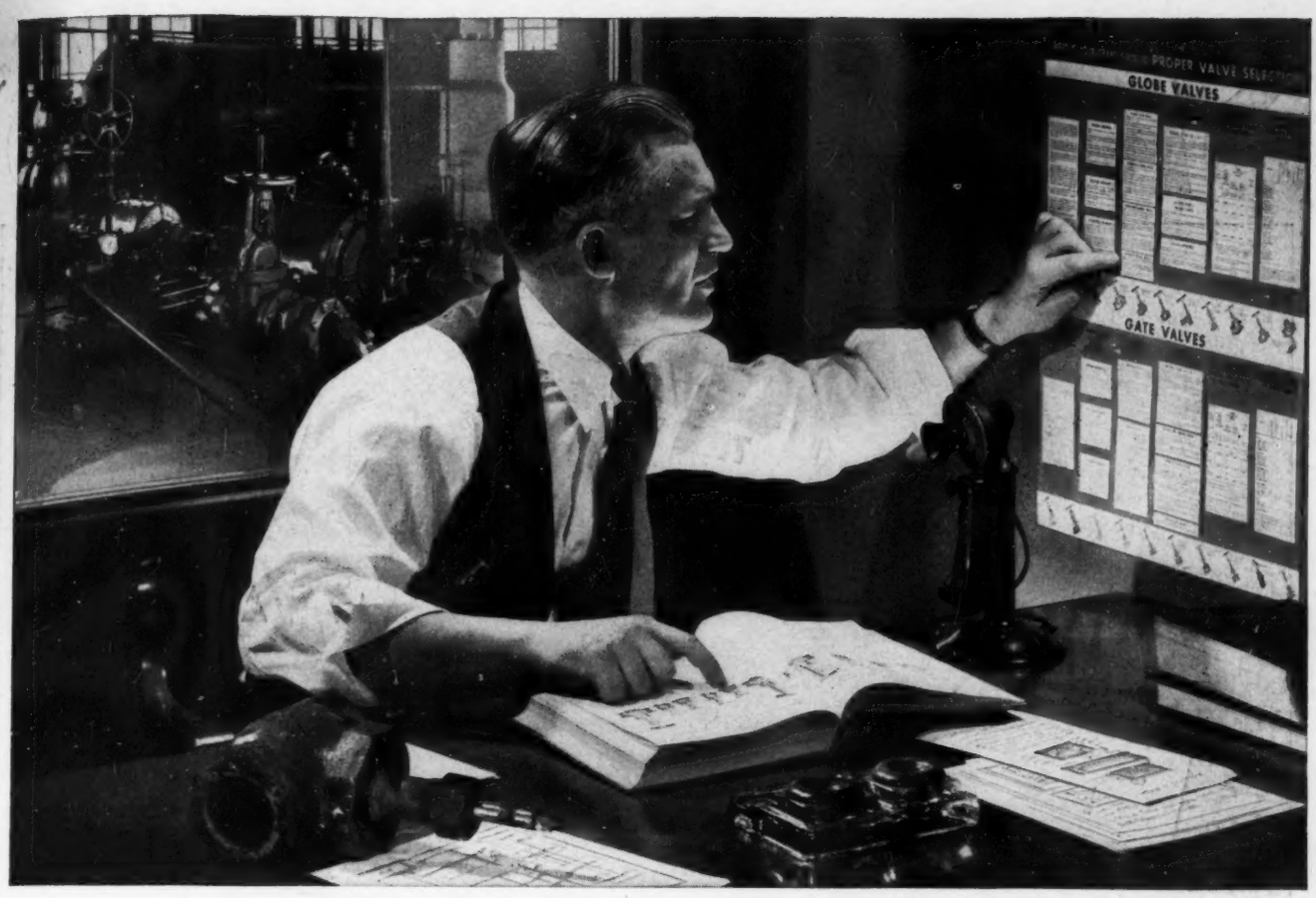

THIS SELECTION GUIDE LEADS YOU TO *Low-Cost Valve Maintenance*

ECONOMICAL valve performance begins with proper valve selection. In the broad line of valve types offered to industry today, there is one that is best suited for each service in your plant—one that will give dependable flow control at reasonable cost. "Trouble spots" and their high maintenance costs often result solely because of a mismatch of valve and operating conditions.

How to Pick the Right Valve

Mismatching of valves and requirements can be avoided. Let Crane's bulletin, "Service Characteristics of Globe Valves and Gate Valves," with its Valve Selection Guide, help you eliminate this hazard in your plant. This guide tells you how well each of the basic valve designs, globe and gate, and their many combinations of disc, bonnet, and stem types, are fitted to service conditions. Such information combined with *your* knowledge of *your* requirements, leads you to the ideal valve for each installation.

And Crane makes just the valves you need—in a quality that promises faithful performance—valves that have the inside stamina to assure low-cost flow control. Your Crane No. 52 Catalog lists more than 38,000 valves and piping items in a complete range of specifications.

Get This Valuable Guide Free

Send for your free copy of "Service Characteristics of Globe Valves and Gate Valves"—put it to use immediately. It takes the guesswork out of valve selection—guides you to piping satisfaction. Mail the coupon—now!

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836 So. Michigan Ave., Chicago, Ill.
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SAVE ON SEWERS

THESE money-saving features of J-M Transite Pipe offer important ways of cutting costs and increasing efficiency on all types of sewer-line systems. The light weight, long lengths and simple assembly of this modern pipe considerably reduce laying costs. Maintenance is negligible because Transite, made of asbestos and cement, is exceptionally corrosion-resistant, uniformly strong. And, in many cases, its high flow coefficient and tight joints permit the use of smaller pipe or flatter grades.

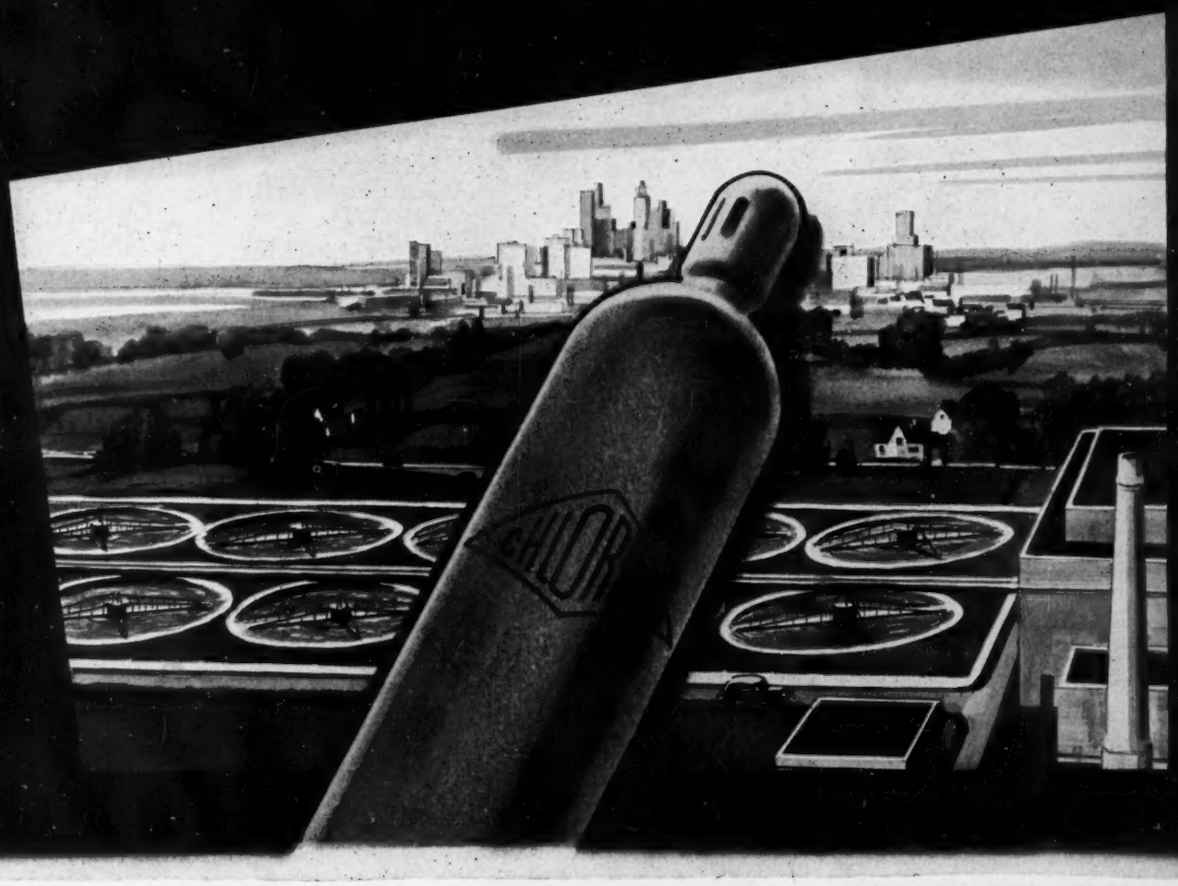
If you are planning a new system or modernizing an existing line, you will profit by getting full details on J-M Transite Sewer Pipe. Write for brochure TR-21A. And, for information on J-M Transite Water Pipe, write for brochure TR-11A. Johns-Manville, 22 East 40th Street, New York, N. Y.

FREE Book Gives Convincing Facts— Write for Your Copy

Johns-Manville TRANSITE PIPE

THE MODERN MATERIAL FOR SEWER AND WATER LINES

DIAMOND LIQUID CHLORINE



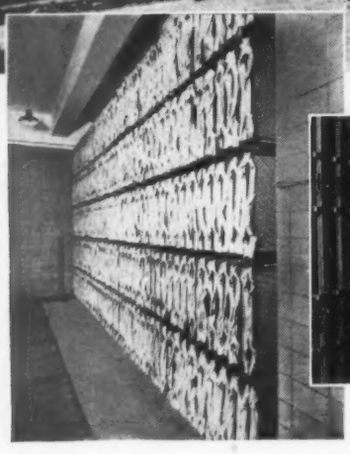
PREFERRED BY MUNICIPAL ENGINEERS!

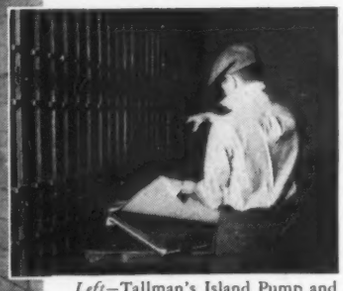
Because of its absolute purity and year around uniformity Diamond Liquid Chlorine assures positive bacterial control under all conditions of service . . . aids modern sewage disposal . . . prevents disease contamination in public swimming pools. Municipal engineers, too, like the quick and prompt deliveries of Diamond Chlorine in the modern trouble-free containers. Your local Diamond distributor will welcome the opportunity to serve you!

DIAMOND ALKALI COMPANY . . . PITTSBURGH *AND EVERYWHERE*

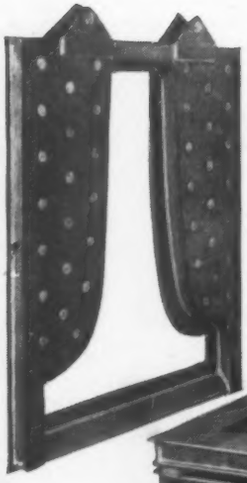
Everdur Metal in these

Tallman's Island
Aerial view of the Tallman's Island Sewage Treatment Works of the City of New York—built to serve the New York World's Fair 1939, and adjacent sections. NORTH-EASTERN CONSTRUCTION CO., New York, and CAYE CONSTRUCTION CO., Brooklyn, were General Contractors.





Left—Tallman's Island Pump and Blower House—outlet end of two-stage air filter. Framework and panels of automatic filters and framework and pockets of the Airmat were fabricated from Everdur Metal by AMERICAN AIR FILTER CO., INC., Louisville, Ky.



Four of these proportional weirs built entirely of Everdur Metal were designed and furnished for Tallman's Island by KRAJEWSKI-PESANT MFG. CORP., New York. Each weir is 5′ wide, 6′ 9″ high, and weighs 1500 lbs

This non-rust, high-strength Copper-Silicon Alloy selected on its 12-year record of dependability in sewage treatment service

THE high regard in which Everdur Metal is held by leading engineers is again typified by its extensive use in New York City's Tallman's Island and Chicago's Southwest Sewage Treatment Plants.

Since 1927 this Anaconda Metal, rustless as copper and steel-like in tensile strength, has proved its dependability in the form of screens, gates, aprons, weirs, bolts, etc., under severely corrosive conditions.

In the Tallman's Island Plant, Everdur Metal was selected for the proportional weirs at the outlets of each of the four grit chamber channels. These weirs regulate the flow between certain limits of velocity, thus securing uniform grit precipitation following the general coefficients of Sutro Weirs. These are of box construction, entirely continuous-seam welded with Everdur rod. Frame plates are held rigid with Everdur staybolts welded in place.

At Tallman's Island, in addition to the proportional weirs, Everdur Metal in the form of sheets, rods, large diameter heavy wall tubes, nuts, bolts, etc., was used for the cylinders, piston rods, attachment parts and slides for the pneumatic grit gates.

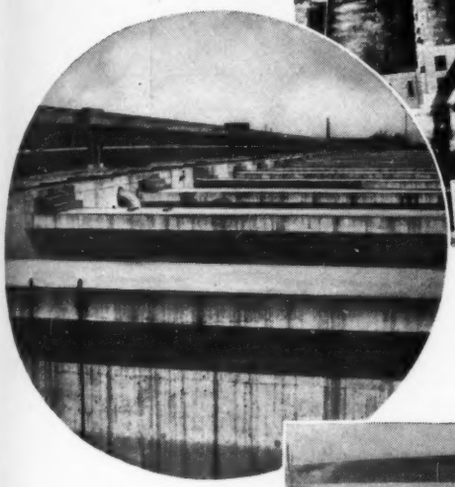
Framework and filter panels of the Automatic Air Filters and framework and pockets of the Airmat were constructed of Everdur sheet and strip.

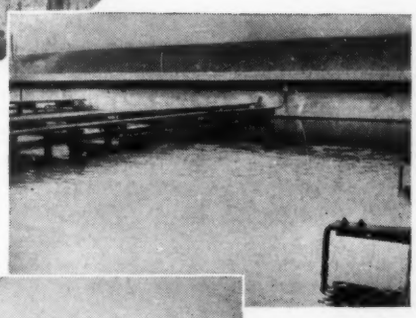
★ ★ ★

Outstanding is Everdur's adaptability to light-weight, wrought, built-up structures. This Anaconda Alloy combines high strength with uniformly excellent resistance to corrosion. It is economical to use, for it is readily workable either hot or cold, and can be welded by commonly-used methods. Anaconda Publication E-11 sent on request.

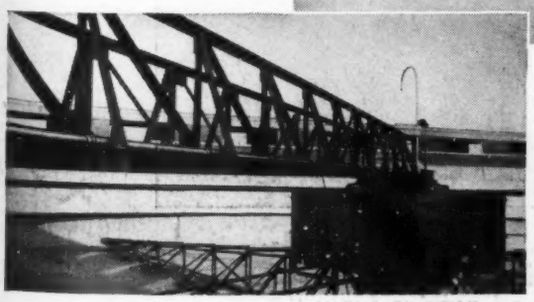
2 outstanding projects

Chicago's Southwest
Aerial view of what will be the world's largest activated sludge plant—Chicago's new Southwest Sewage Treatment Plant. Plan provides for enlarging the capacity (now 400,000,000 gallons per day) to as high as 1,200,000,000 gallons per day.





Showing non-rust, high-strength Everdur EMT installed for conduit in Chicago's Southwest Plant. Electrical Contractors were Central States Electrical Construction Co., and Harmon Electric Co., Chicago.



ANACONDA
from mine to consumer

100,000 lbs. of Everdur for conduit lines in Chicago's giant new Southwest Sewage Treatment Plant

EVERDUR EMT (Electrical Metallic Tubing) was selected for electrical conduit because of its high physical properties and excellent resistance to such corroding agents as hydrogen sulphide, carbon-dioxide, moisture, and oxygen.

From two to four lines of Everdur Conduit run the full length of the 1088-ft. operating galleries. Everdur Conduit also carries power from the operating galleries to operate sluice gates at the control centers for the final settling tanks. Everdur Conduit leads out from the control centers to the operating mechanism on the center pier of each of the final settling tanks. In all, a total of approximately 14 miles of Everdur Conduit in sizes from ¾" to 2½" inclusive was used in this installation—about 80,000 lbs. of EMT and 20,000 lbs. of fittings and boxes.

Everdur Electrical Conduit is manufactured in standard sizes and in two wall thicknesses (EMT and RC). It is listed and labeled by Underwriters' Laboratories. Seamless, of uniform temper, and accurately cold drawn to size, Everdur Conduit can be cut, threaded, bent and assembled in practically the same manner and with the same equipment employed for steel conduit or tubing. Publication E-12 on request.

Everdur Metal

THE AMERICAN BRASS CO., General Offices: Waterbury, Conn.
In Canada: Anaconda American Brass Limited, New Toronto, Ontario
Subsidiary of Anaconda Copper Mining Company

EVERDUR is a trade-mark of The American Brass Company, registered in the United States Patent Office. 89147

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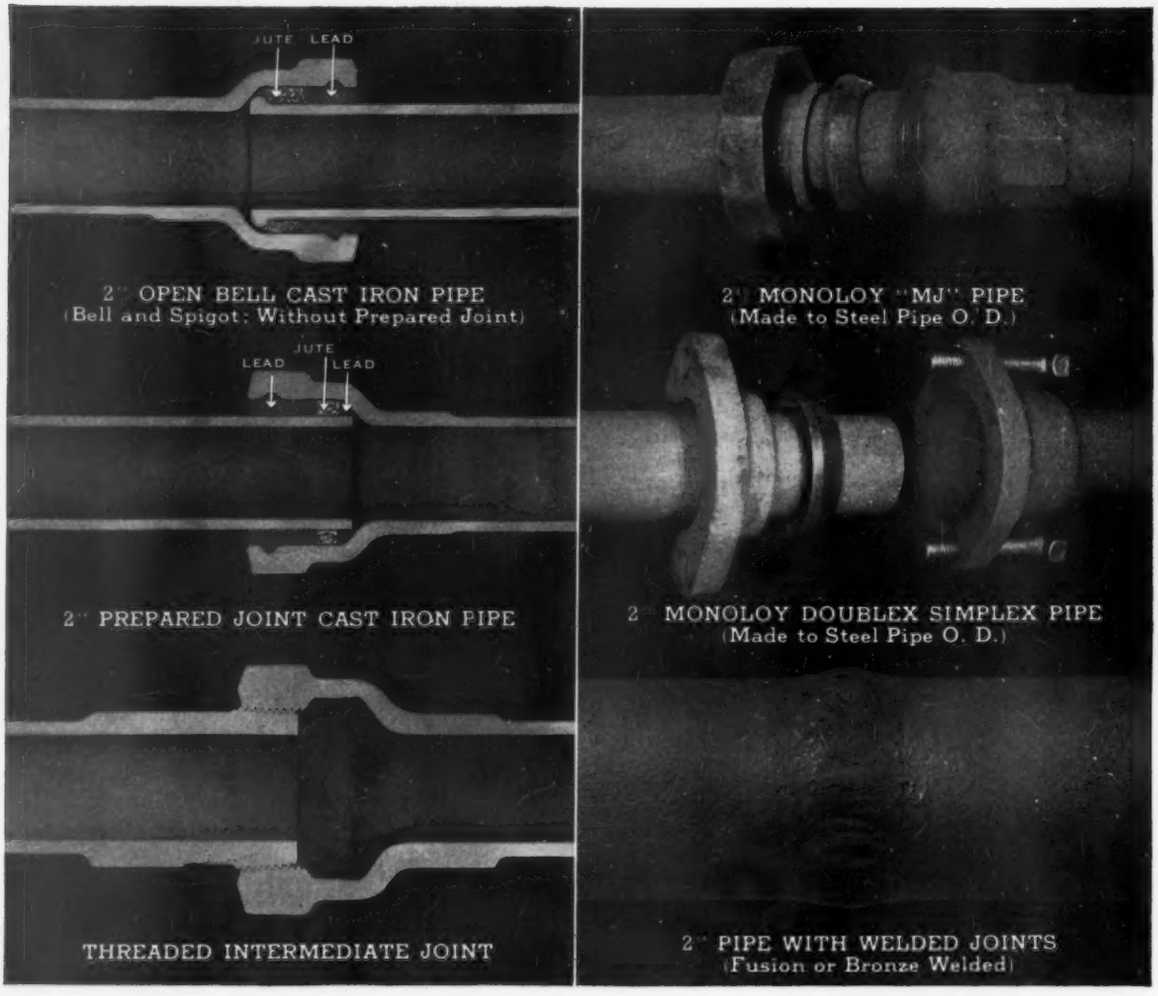
2" CAST IRON PIPE

"Acipco" 2-inch Cast Iron Pipe introduces the permanence, dependability and economy of Cast Iron Pipe into small service and distribution lines, building piping, small pump lines and various miscellaneous uses. "Acipco" was the pioneer developer and is one of the industry's largest producers of 2" and other small-diameter pipe. A wide variety of joints and complete line of 2" Cast Iron Fittings is available. Write for detailed information.



"Acipco" manufactures a complete line of Cast Iron Pipe and Fittings in diameters from 1¼" to 36" inclusive. Whatever your pipe requirements, address "Acipco" office nearest you, and enjoy peak quality of product and service from "America's Largest Individual Cast Iron Pipe Foundry."

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BADGER *Water* **METERS**

If you were "writing your own ticket"

For the Ideal Water Softening Plant

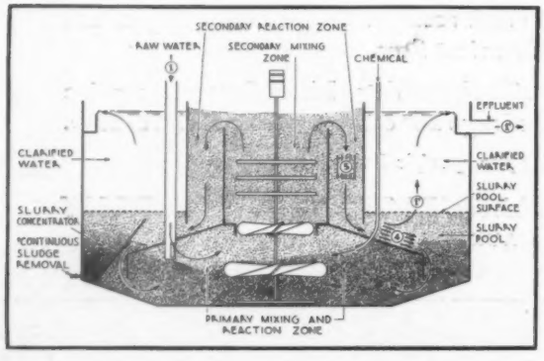
● You would want a plant that could be stopped whenever necessary and when started again would immediately reach full operating efficiency.

● You would want the plant flexible enough to handle flows from a very low rate to rates even in excess of normal capacity, all with the same uniformly satisfactory results.

● You would want operating expenses to be at the absolute minimum—which would mean full use of treating chemicals without unused lime passing to waste.

● You would want all treatment steps combined and centralized for economy in construction, maintenance and operation.

● You would want the plant to require as little space as consistent with best results.



● You would want sludge removal to be continuous and automatic.

● You would want the softening process to be simple, and fool-proof in operation to assure dependable performance.

● Naturally you would want the effluent constantly uniform and of low hardness and turbidity.

● You would want the plant to be of the most up-to-date and modern type available.

● But at the same time you would want the plant to have *known* ability—to have proved itself in scores of successful applications—*you would want it to reflect your good judgment in its selection.*

You've Specified the Accelator!

In "writing your own ticket" for the *ideal* softening plant, *you've specified the Accelator.* Feature by feature, it satisfies every requirement—The Accelator *is* the ideal softening plant. Bulletins 1820, 1821 and 1822 tell you why. Write for them — they are free.

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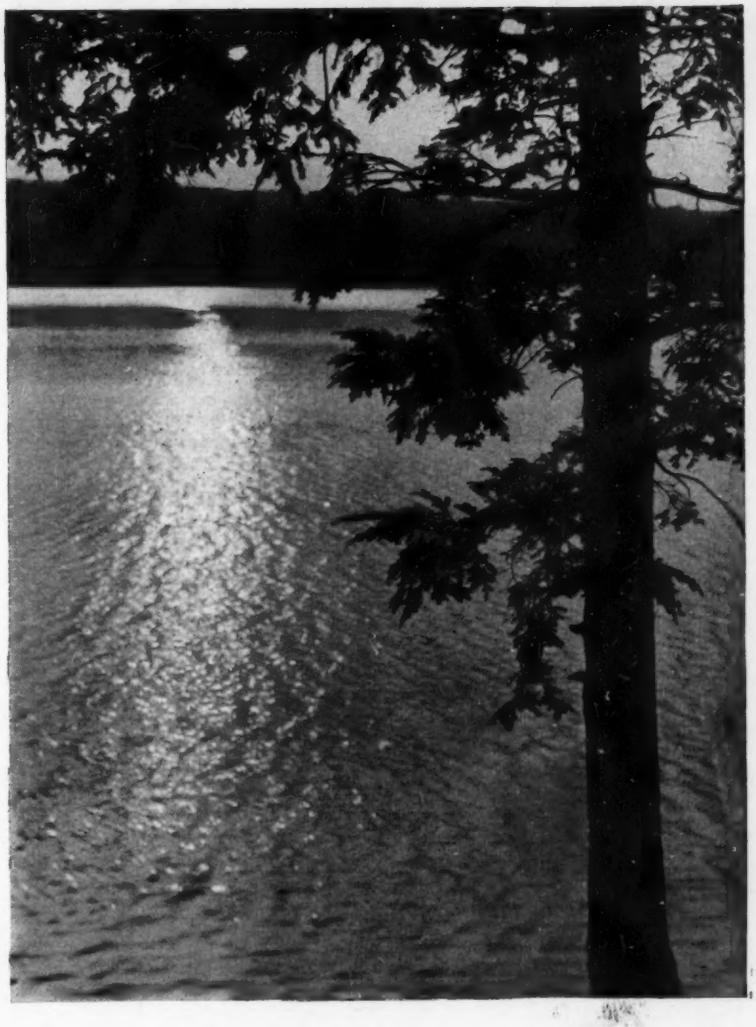
Standard SILICATE

Reduces WATER TREATING costs



Municipalities, industrial plants, textile mills find that the addition of Standard Silicate saves up to 45% of the lime and alum or ferrous sulphate needed to properly clarify the water supply. This new process can also be applied to increase the capacity of existing water filtration plants.

Our technical staff will gladly demonstrate how this saving can be accomplished.

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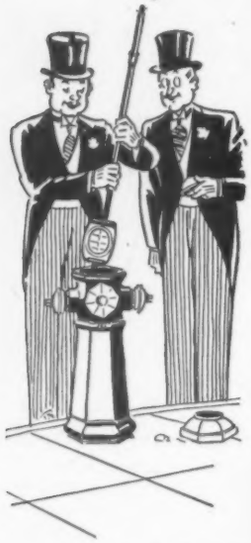
THE BEST Hydrant PROVIDES Easy Inspection

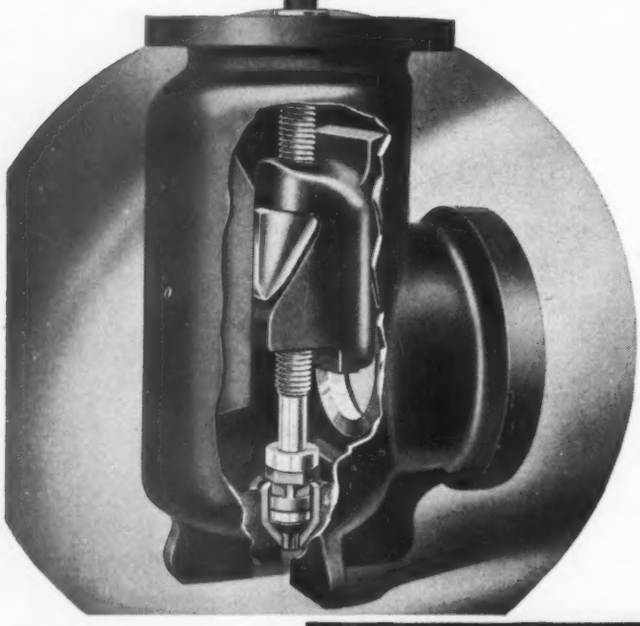


A hydrant must allow easy inspection and servicing. The *best* hydrant, therefore, permits the removal of *all* working parts as *one unit* by lifting stem through top of hydrant, *without unscrewing anything below the ground level.*

The best hydrant also provides *quick* water with least possible shock, and shut-off without water hammer. It is properly drained at the *lowest* point. It will not flood when broken, because the gate is wedge-locked.

Only the slide gate principle provides *all* these advantages. This principle, developed and perfected by Ludlow, has been the universally accepted construction in all *water works valves* for nearly three-quarters of a century. It likewise insures *complete security* in fire hydrants.

Information free on request.



Construction is such that all working parts can be taken out as a unit without any digging or disturbing barrel or seat ring.

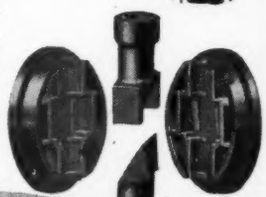
THE BEST Valve ALLOWS Ready Replacement of Parts

A valve must be easy to repair. The best valve therefore guarantees ready replacement of parts with simple internal construction and ample tolerances; new parts match the old, even after years of service.

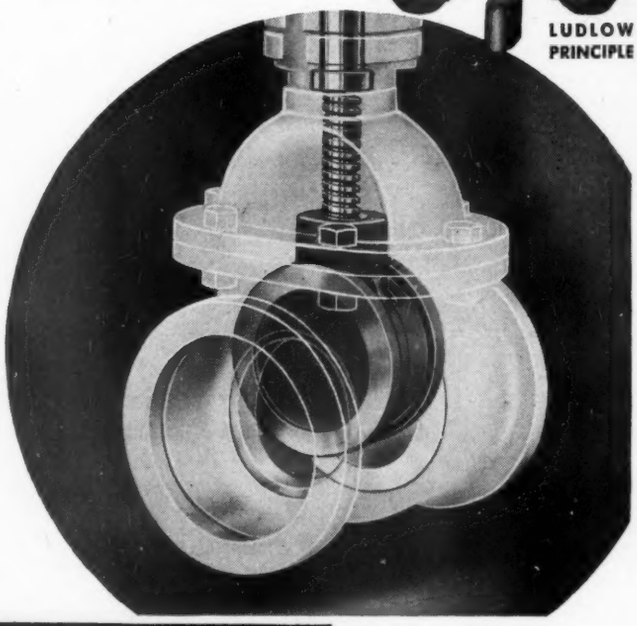
The best valve also assures smooth, positive operation by unwedging and freeing gates *before* raising, wedging them only when they are directly opposite ports. It cleans itself and has no internal guides to cause foul-ups. It guarantees positive closure with self-releasing 30° angle wedges, and flexible-action gates *self-adjusting* to seats.

Only the parallel seat, double wedge type slide gate valve provides *all* these essential benefits. This principle, developed and perfected by Ludlow, has been the universally accepted construction in all *water works valves* for nearly three-quarters of a century.

Information free on request.



LUDLOW PRINCIPLE



One stem, two gates, and two bevel-face wedges constitute all working parts. Even after years of continuous operation, new parts fit with the old.

The LUDLOW VALVE MFG·CO· TROY·N·Y· SINCE 1866

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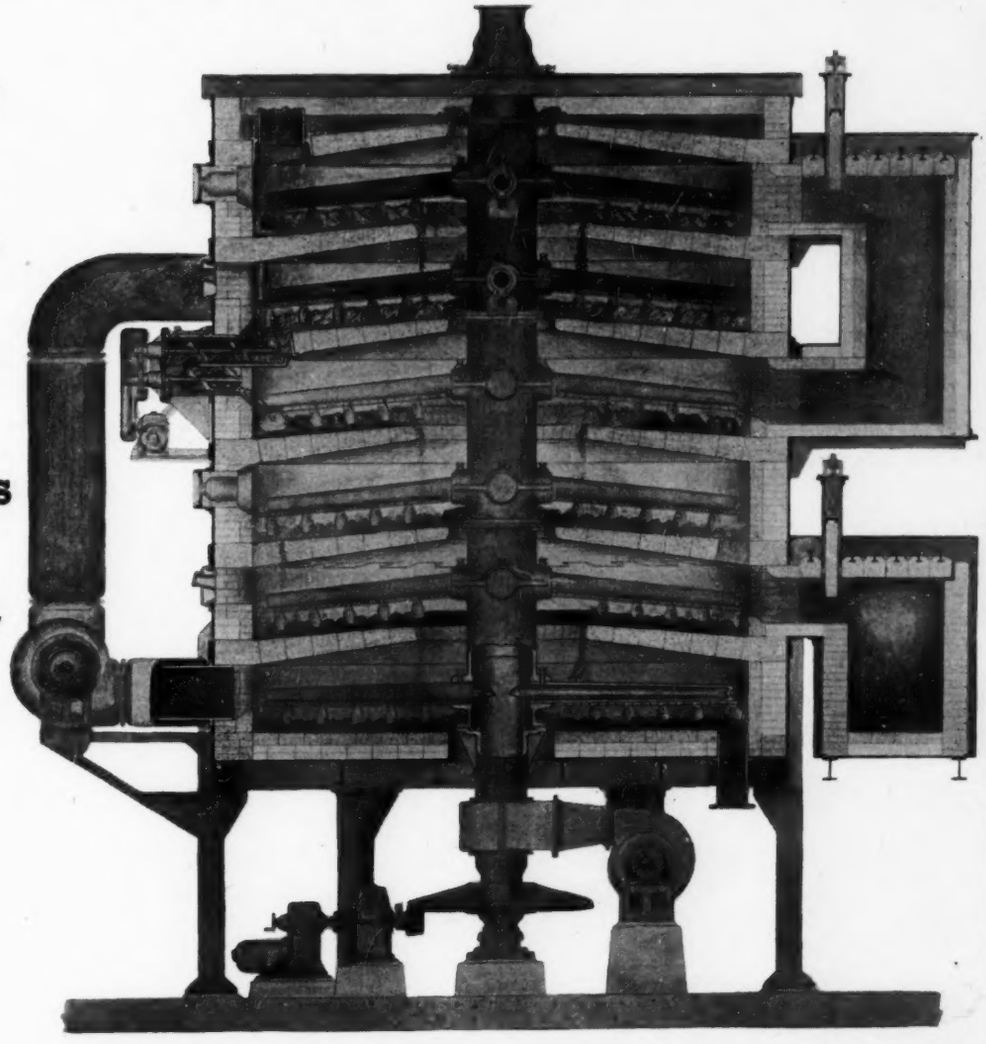
FOR INCINERATION OF SEWAGE SLUDGE, SCREENINGS and GROUND GARBAGE

OPERATION IS WITHOUT AUXILIARY FUEL— ODORLESS!



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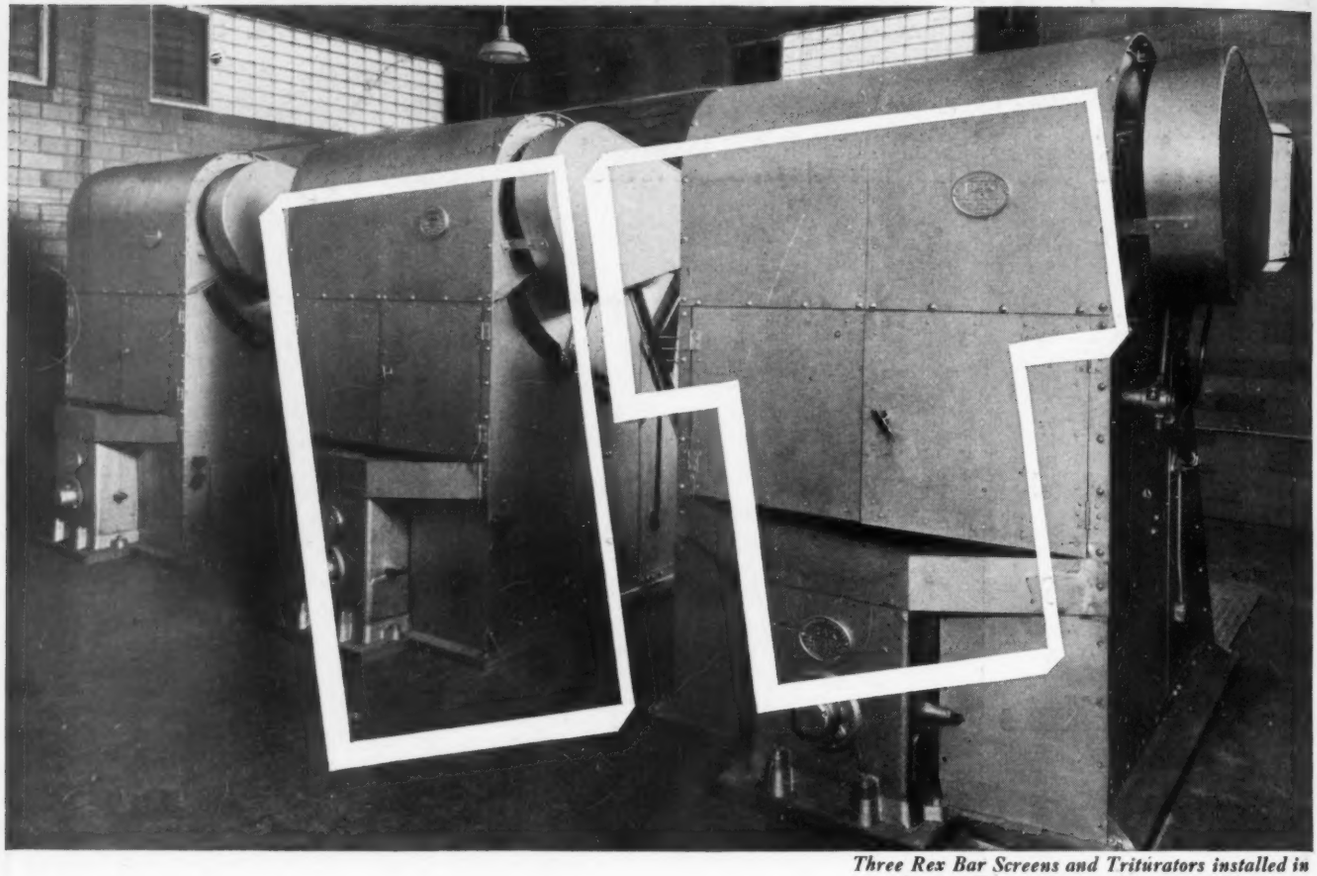

Three Rex Bar Screens and Triturators installed in the new Denver Sewage Treatment Plant

IF *IT* IS SCREENING AND DISPOSAL

BEFORE YOU BUY—CHECK UP ON PAST PERFORMANCE!

Before making a final decision on screening and disposal equipment, experienced sanitary engineers give due consideration to satisfactory performance as demonstrated in actual service. They make certain that this actual service is under conditions sufficiently exacting to demonstrate ability to meet emergency, as well as normal, requirements. Low head loss, low maintenance cost, rugged design, and easy accessibility to all operating parts are important practical considerations—time-proved by actual experience.

Rex Triturators and Rex Mechanically Cleaned Bar Screens meet these practical requirements—have demonstrated their ability to do a thoroughly satisfactory job under the "toughest" operating conditions—in all sizes and types of plants. Your confidence and expectations will be justified by performance when your choice is Rex Triturators and Rex Mechanically Cleaned Bar Screens.

For complete and detailed information on the Rex method of screening and disposal, address the Sanitation Equipment Division, Chain Belt Company, 1610 West Bruce Street, Milwaukee, Wis.

The Rex Triturator and Rex mechanically-cleaned bar screen form a simple, compact, easily serviced unit—an asset to any sewage treatment plant in performance and appearance.

REX SANITATION EQUIPMENT

CHAIN BELT COMPANY of Milwaukee

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VALUABLE PUMP DATA FOR ENGINEERS AND PUMP STATION DESIGNERS

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Prepared especially for the use of Engineers and Pump Station Designers, these two new bulletins contain the latest engineering data and specifications on the complete line of Fairbanks-Morse Sewage and Trash Pumps.

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Gentlemen: Please mail free copies of the new Fairbanks-Morse Sewage and Trash Pumps Bulletins 5410B and 5410C.

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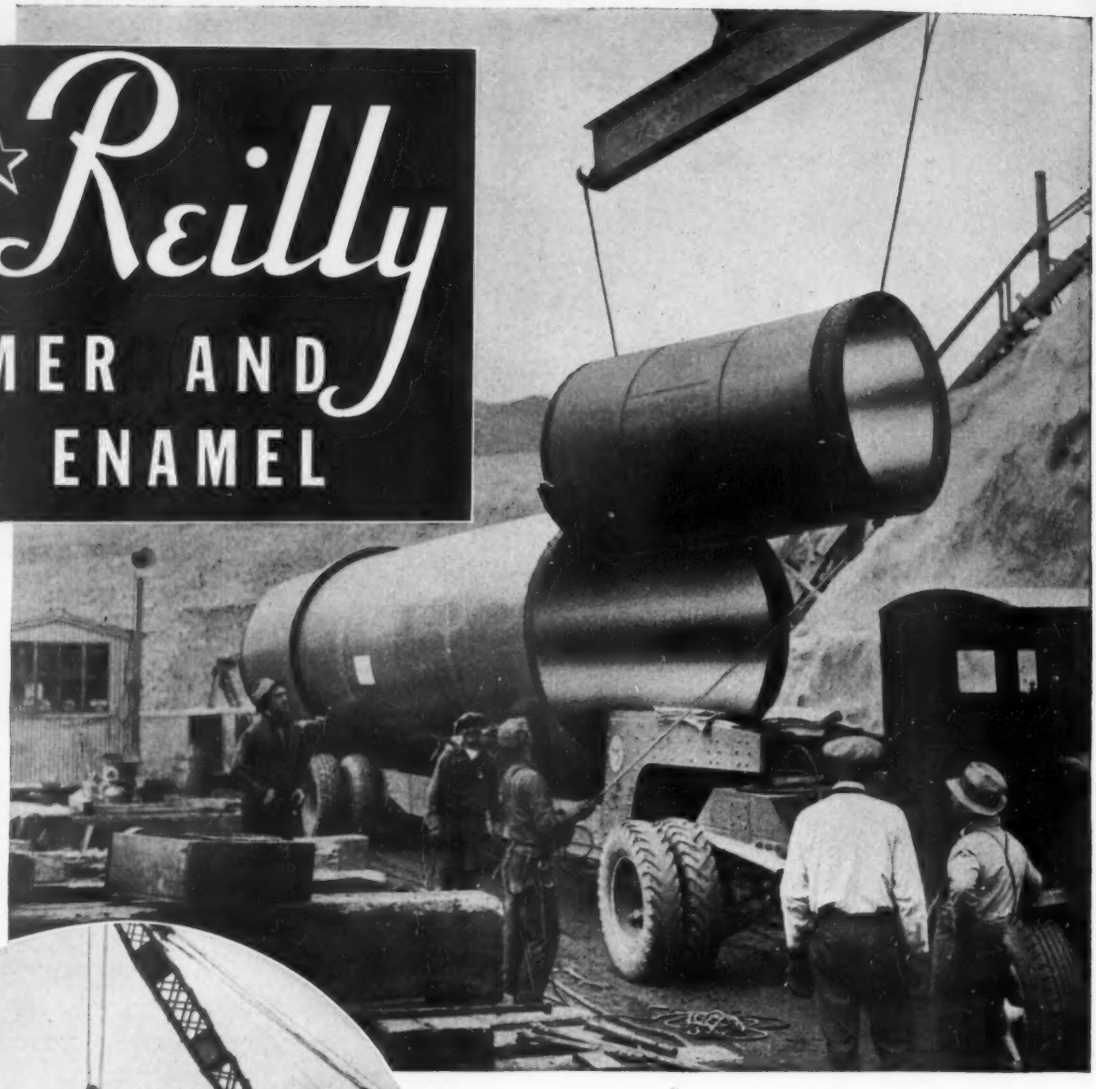

● In all water works projects, permanent protection against rust, corrosion and tuberculation is assured, and full capacity flow maintained, by the use of REILLY interior and exterior pipe coatings. Maintenance and repair costs are reduced to the minimum.

REILLY PRIMER and PIPE ENAMEL give a tenacious bond to the metal. Reilly coatings are highly resistant to abrasion and withstand wide changes in temperature without sag, flow, chipping or cracking. Easily and quickly applied by any of the usual methods. Ask for literature and complete information.

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WATER WORKS & SEWERAGE

Published Monthly by Gillette Publishing Company

PUBLICATION OFFICE
330 South Wells Street Chicago, Ill.
E. S. Gillette, Publisher

EDITORIAL OFFICE
155 East 44th Street New York, N. Y.
L. H. Enslow, Editor

Coming!

Articles

"The Adaptability of Various Pipe Line Materials in Water Main Construction"
(An analytical study and critical comparison of values in pipes of various materials when making long time estimates, involving known mechanical characteristics, useful service life expectancy, dependability, and projected ultimate costs.)

"The Design of Air Distribution Systems for Activated Sludge Plants"
(An especially valuable contribution dealing with a topic about which little concrete information has been available. Design, considerations with respect to sufficiency vs. first costs vs. operating savings over a period of years, are based on Chicago studies supplemented by experience.)

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(Installment No. 3 of a series of timely articles full of up-to-the-minute information of value to plant operators and designers, with especial reference to the care, maintenance and operation of dewatering equipment, methods of sludge conditioning, and overall economy.)

"Methods and Devices for Improved Flocculation"
(The topic was developed in a symposium of four papers presented before the Sanitation Group of the Am. Soc. of Mechanical Engineers. Through the courtesy of the Society these worthy papers will be available to our readers.)

"Experiences with Gas Purification"
(Is one of a series of articles on sludge gas utilization in power development with gas engines. This article reveals helpful information on gas scrubbing. equipment involved, and operating experiences.)

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Entered as Second Class Matter, June 2, 1931, at the Post Office at Chicago, Ill., under the Act of March 3, 1879. Published monthly at 330 S. Wells Street, Chicago, Ill. Per Copy, 50c. Subscription rates, United States and Canada, $2.00 per year; Foreign, $3.00 per year. Copyright, 1939, by Gillette Publishing Company, Publishers of: Water Works and Sewerage, Roads and Streets, Mida's Criterion, Oil and Soap, Powers' Road and Street Catalog and Data Book.

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Chicago Office, 330 S. Wells Street. Cleveland Office, 1217 St. Charles Avenue, Lakewood, Ohio. New York Office, 155 East 44th Street, San Francisco Office, 155 Montgomery Street, Los Angeles Office, 318 W. Ninth Street.

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Editorial

On ATTAINING SUCCESS in WATER WORKS OPERATION

REEVES NEWSOM*

Guest Editor

LIKE formulae of success in any field, the one for the water works operator is not composed of a definite number of algebraic factors. Rather, it consists of certain personal characteristics, the determination to acquire from those who have gone before all possible benefit from their experience, and the ability based on knowledge of one's business, to take full advantage of such fortunate breaks as one gets, thus proving the capacity to do even bigger things.

While the job of operating a modern water works system, the function of which is to furnish safe and finely conditioned water at the lowest possible cost, has become increasingly complex in the last decade, the opportunities for learning how to do such a job have more than kept apace. There is no reason today why any young man, given a reasonable amount of what is generally described as "a pleasing personality", cannot become a successful water works operator if he will take full advantage of the opportunities available to reinforce the weaknesses in his education or training and to improve his judgment.

Emphasis is put on personality because of certain characteristics of the water supply business. It is, in the first place, a fundamental public service and because the public is notoriously ungrateful, and slow in recognizing merit and ability in its servants, the water works operator must take it on the chin frequently without its disturbing either the smile on his face or his sense of humor underneath. Further than this, because water comes free from the heavens and has always been easily available to most people now receiving water service, it is taken for granted more than is any other utility service. The operator's contacts with his customers, therefore, are largely under unfavorable circum-

**President*
American Water Works Association

stances and usually have to do with complaints regarding the service or its cost.

The success of the water works operator deepnds to such a great extent on his ability to handle that part of the public which has a grievance, not only in person but through the selection and training of his assistants, that the right type of personality must be listed high in the requirements for success.

Next comes the readiness to learn from the older employees of the department all that they know of their respective jobs, coupled with an inner determination not to accept as good practice anything that has "always been done that way" just for that reason. To assume that the new broom must sweep out all old methods and practices is just as foolish as to be willing to coast along with things that apparently have been successful for many years. Modern water works practice has many new things in it and the apparent success of some old methods may be only because no comparison has been made with what is now available. However, intelligent selection of what to retain and what to discard remains important, and there must be combined with the making of any changes the ability to "sell" the new things to the older employees in such a way that they will not resent giving up pet hobbies, even when these can be proved inefficient. New materials, new equipment or new methods of work which replace those formerly used, many times fail to "pan out", to the injury of the head of the department and his future accomplishments; all because of the mistake of not taking the time and trouble to convince those under him of the merits of such changes before making them.

Loyalty and enthusiasm on the part of all employees in the system for the superintendent and his ideas is a "must" in any formula of success as a water works operator. The ability to gain them requires tact and understanding of the points of view of others. But the chief will never hold his employees' loyalty if he makes foolish mistakes and risks changes that do not work as well as did the things replaced. Therefore the young operator who really expects to "go places" must "know his stuff" before he springs changes on the hard-boiled men around the plant who have been furnishing water service for years.

Today this is no real problem. For $2000 there will be made available to him the opportunity to compensate for substantially every deficiency in his education and experience. And he doesn't need to have two thousand if he can raise the interest on $2000 each year, preferably from his city, for the city's gain is even greater than that of the individual. He will have a vast store of knowledge and personal experience opened to him. He can join the American and other Water Works Associations. He can attend the meetings of his state section and there meet other water works men and discuss with them joint problems. He will receive the journals giving all the important developments in the entire country set out in form for him to incorporate in the solving of his problems. Assuming his intensity of purpose, he can attend the short-school held in his state each year and there receive a concentrated education on the practical phases of the theories of water purification and hydraulics designed for easy assimilation. Furthermore, he should miss no opportunity to visit representative water plants, for there he may learn at first hand how the other fellow meets his difficulties. For the interest on even half the sum mentioned he can get a great part of these advantages. So no good reason now exists why any operator should make mistakes either of commission or ommission that will interfere with his advance to success.

To hold success as attained, he must be willing to go beyond being just the local water superintendent and enter into the many community and civic activities to which his stability and training make him a valuable asset. His willingness to lend his efforts will not only assist in gaining for him the place and prestige in his community to which he is entitled, but will react to the credit of his department, produce on the part of the public a willingness to learn and sympathize with the problems and aims of the water service, and thus bring about that ideal condition where the operator is left free of interference to do a real job for an understanding and respectful public. Under such circumstances he will have achieved that measure of satisfaction and happiness which is the test of any formula of success.

Reeves Newsom

We wished to treat editorially "Some of the Things It Takes to Attain Success in Water Works Operation." In looking for a pattern of one who had attained such success, we logically thought of the President of A. W. W. A. Then our next thought was why not invite him to become our Guest Editor and write something of his own ideas on this topic.

We take a great deal of pleasure in the fact that Reeves Newsom accepted. And herewith we present a "Formula" as it is seen by a man who began his successful career as operator of municipal water plants and in eleven years of association with privately owned plants rose to the position of Chief Operating Engineer at the age of 32 and, later to that of President of The Community Water Service Co., then operating 43 water utility properties.

We hardly think that we could have chosen one to better exemplify the topic on which he has written.—*Editor.*

WATER WORKS & SEWERAGE

VOLUME 86, NO. 5 *A Gillette Publication* MAY, 1939

PRINCIPLES OF POWER GENERATION WITH SEWAGE-GAS ENGINES

The Author

By NORMAN C. WITTWER

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MANY interesting accounts of sewage-gas engine power generating installations have been published in the engineering literature during the past several years. Several of these, particularly the articles of Walraven (1) and Sperry (2), in WATER WORKS & SEWERAGE and *Sewage Works Journal* have been outstanding in the technical thoroughness with which the authors discussed their experiences with this new and valuable adjunct to sewage treatment.

The writer has recently had occasion to make a comprehensive study of the feasibility of power generation with sewage-gas engines for the Sewage Treatment Works of the Rahway Valley Joint Meeting. The results of this study indicate that a very substantial saving in power costs is possible by the substitution of gas-engine generator sets for the present public utility power. Our current annual power bill is approximately $5,700.00 which covers the cost of pumping all sewage entering the plant, power for all auxiliary pumps and mechanical equipment, and lighting.

It should be pointed out that the only justification for making a capital expenditure for power generating equipment to supplant outside power service must lie in the *net* annual savings in power costs which may be derived. The considerations for or against such an installation must be purely financial, as the self-generation of power will not add to, or detract from general sewage plant operation, or the results to be obtained from the treatment processes.

Arrangements Possible

Many arrangements are possible by reason of which the installation of sewage-gas engines may prove to be desirable. Some are as follows:

1. Engines direct-connected to sewage pumps where all or part of the plant flow is pumped.

2. Engines direct-connected to blowers used for aerating sewage.

3. Engines direct-connected to generators for the generation of all or part of the electric power required.

4. Engines direct-connected to miscellaneous items of mechanical equipment.

This article will present the technical and economic phases of a complete power-generation plant designed to provide power for *all* the operating requirements of the Rahway Valley Sewage Treatment Works. While the Rahway Plant is a primary treatment plant having a capacity of 25 mgd, the type or size of plant does not in itself control the economics of sewage-gas power production. A number of factors influence the problem, and each should be thoroughly studied. They are as follows:

1. Experience at other sewage treatment plants where sewage gas power is being used.

2. Power requirements for the service desired—average and peak loadings

3. Size and type of generating units required.

4. Standby power service.

5. Quantity and dependability of

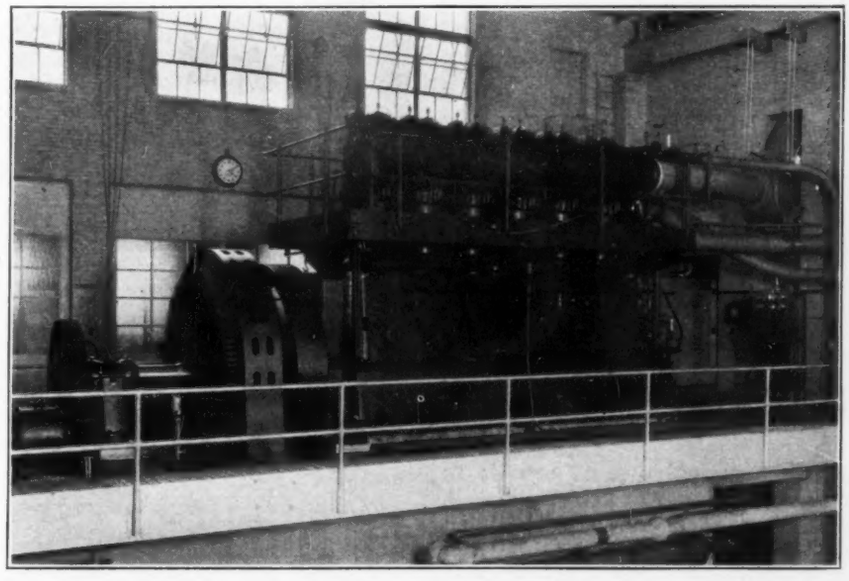


Fig. 1—The 1200 H.P. Rathbun-Jones Engine-Generator Set at Washington, D. C.

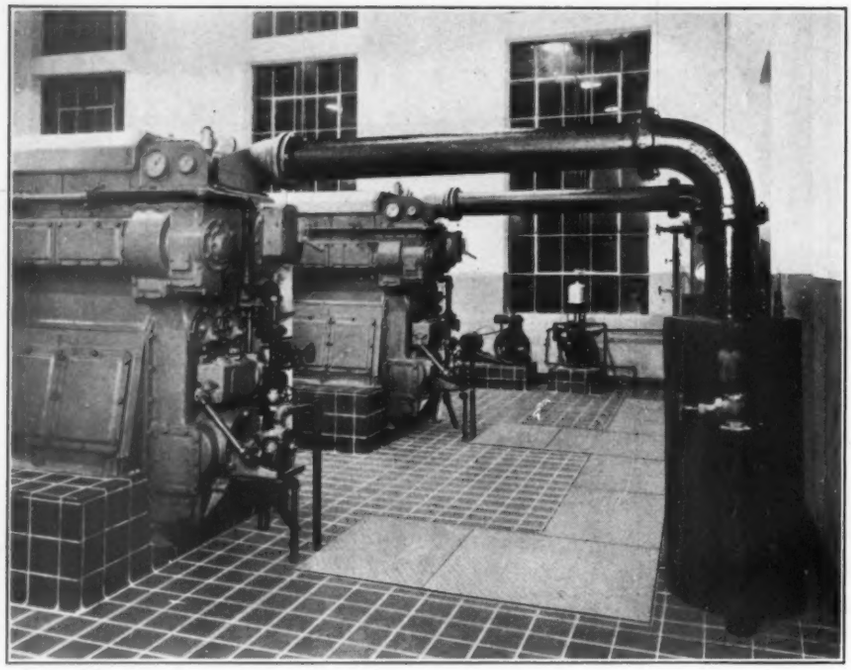


Fig. 2—Twin 150 H.P. Cooper-Bessemer Engine Generator Sets for Durham, N. C. (Note waste-heat boilers on right)

gas supply as compared to the average and peak power requirements.

6. Heat recovery for the heating of digestion tanks and buildings.

7. Probable first cost.

8. Annual interest and amortization charges.

9. Operating and maintenance costs.

10. Annual savings, if any, as compared to the present power costs.

Experience at Other Sewage Treatment Plants

It was first thought advisable to investigate the experience at other sewage treatment plants where gas engines are in use. Accordingly, questionnaires were sent to a number of sewage treatment plants which have been using sewage-gas power over varying periods of time. The information obtained from these questionnaires is tabulated in Table 1, and may be summarized as follows:

1. Three plants from which replies were received were larger than our plant, ten were smaller.

2. All showed a net annual savings. Some indicated that interest and depreciation were first charged off; the others did not clearly stipulate.

3. The annual cost of repairs as compared to power production in most cases is very low.

4. The annual cost of lubricating oil in most cases is very low.

5. In most cases, a statement was made to the effect that the engines were operated by the regular force, with no additional men.

6. Each reply indicated that sewage-gas generation of power is satisfactory and practical.

Power Requirements

The power requirements for a new plant must be estimated, but for a plant in operation with a back-log of operating records, the present and probable future requirements can be determined with a fair degree of accuracy.

By an examination of the first three columns of Table 2 under the heading "Hourly Rates of Power Consumption," it can be seen that the hourly power demand during an average day for the Rahway Valley Plant approximated 40 KWH during the first ten months of 1938. The hourly average of a maximum day during this period was 114 KWH, while for a minimum day it was 23 KWH. Temporary demands higher than 114 KW have been recorded on the local power company's demand chart, the highest being 124 KW during a heavy storm in September. Such extreme peak demands, although not frequent, do occur occasionally.

From these records, the following power requirements were determined:

Average	40 KWH
Moderate Peak	99 KWH
Extreme Peak	124 KWH

A generating plant to take care of the above loadings will be as follows:

One 60 KW generator set to provide power for average demands, with sufficient reserve power for minor fluctuations.

One 60 KW generator set to serve as alternate to the first set, and to provide the additional power required for the peak demands.

Note:—Both generators operating in parallel will generate 120 KWH, and will easily stand the temporary overloading required to produce 125 KWH.

Some form of standby power service is always desirable. If the charges are within reason, an outside power company connection is the most practical. If such charges are too high, and they usually are, an arrangement may be made to use the local gas company's gas in case the supply of sewage gas fails. The scheme has proved entirely feasible and economical at existing plants.

If gasoline is to be used, a carburetor should be provided on the engine by means of which the engine may be operated as a gasoline engine. In the case of the Rahway Valley Plant, it is intended to cut off the local power company entirely and to use gasoline as the auxiliary fuel to serve as a standby.

Selection of the Engine

The More Important Considerations

Many gas engines are on the market, some of which have been especially adapted to the use of digester gas as a fuel. The most serviceable type is the heavy-duty, slow-speed engine. Such engines are built to run continuously for a number of years with low cost of repairs and maintenance, and embody the standards of construction and the principal features of the heavy-duty Diesel engine.

Some sewage treatment plants have installed the lighter-weight, higher-speed automotive type of gas engine which is less expensive in first cost. However, experience has proven that in general these engines cannot be subjected to continuous service over protracted periods of time without high maintenance costs. In addition, their total useful life is much shorter than that of the heavy-duty engine, so that in the long run, the heavy-duty engine may be expected to prove the more economical type.

The special features to be considered in choice of engines are those involving long life and low maintenance costs. Valve-in-head engines are preferable in the smaller sizes.

In the larger sizes, valves should be in removable cages, or should be otherwise easily removable for convenience in inspection and grinding of valves. Renewable valve-seat inserts should be provided for the exhaust valves, preferably of some high grade heat resisting metal such as "Stellite."

An engine of unit-block frame type, bolted direct to the engine base, is preferred. Each cylinder head should be a separate casting, and renewable cylinder liners of a high strength material should be provided so that wear in a cylinder will require the replacement of a liner only, rather than a complete cylinder. It was found at the Coney Island (N.Y.) Plant that the liners can stand three reborings before replacement is necessary.

The main bearings should be lined with a high-grade anti-friction metal, and should be fitted so that they can be removed without disturbing the crankshaft. Easy access should also be provided to the connecting-rod bearings. Water jacket space should be accessible for cleaning through ample covered openings inside of the frame.

When the engine is direct-connected to a generator, a fly wheel should be mounted on the drive end of the crank shaft. It should be dynamically balanced and have sufficient inertia to insure the degree of uniform rotation required for generator operation. A governor should be provided which will satisfactorily control the speed of the engine to the limits required for the guaranteed operation of the generator.

The customary oil filter and air filter should also form a part of the installation. Safety devices are also very desirable, such as an electric alarm and automatic shutdown system, to protect the engine against low lubricating oil pressure and excessive jacket water temperature.

The desirable features *not* customarily found on automotive types of engines may be summarized as follows:

1. Unit-block frame bolted direct to engine base.
2. Cylinder heads as separate castings.
3. Renewable cylinder liners.
4. Renewable valve-seat inserts for exhaust valves.
5. Valves readily removable.
6. Main bearings mounted in engine base.
7. Main bearings readily removable.
8. Water jacket space accessible for cleaning.

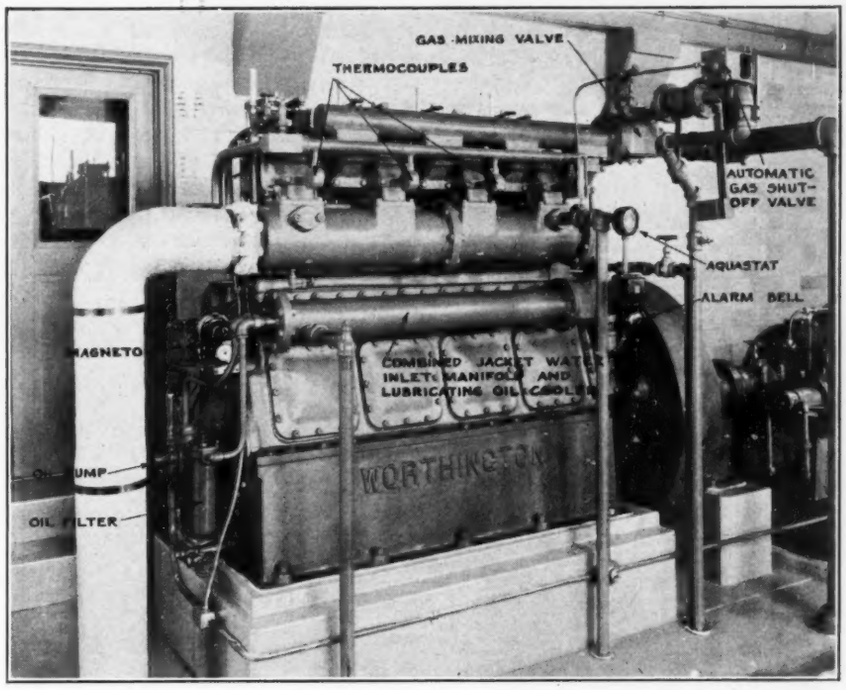


Fig. 3—Worthington 120 H.P. Engine at Ann Arbor, Mich. Direct Connected to Blower

9. Flywheel, if engine drives a generator.
10. Governor to control engine speed.
11. Safety devices.
12. Piston speed not to exceed 1000 feet per minute.
13. Brake mean effective pressure not to exceed 70 pounds per square inch.

Quantity, Quality and Dependability of Sludge Gas

The evolution and production of sewage gas is normally a continuous and uninterrupted process, resulting from the biological decomposition of sewage sludge in digestion tanks. During this process a portion of the volatile organic matter in the sludge is converted into a cumbustible gaseous mixture which is approximately

Methane	64%
Carbon Dioxide	30%
Nitrogen	5%
Hydrogen Sulphide	Trace
Other Gases	1%

Weekly analyses of the gas at Rahway have been run since the plant was placed under operation. From these analyses (made with a Bureau of Mines Gas Analysis Apparatus) the average heat value of the gas has been found to be about 650 Btu. per cubic foot. This is slightly higher than commercial gas, which runs about 550 Btu. per cubic foot. In an internal combustion engine, about 10 percent of this heat is not available, this being the heat of vaporization. Thus the dependable minimum heat value of the gas becomes 575 to 600 Btu. per cubic foot.

Importance of Gas Storage

Table 2 indicates that a uniform and dependable supply of gas is available at our plant at all times. The average daily gas production for January to October was 71,000 cubic feet. However, since individual days have shown productions as low as 60,000 cubic feet, it has been assumed for the purpose of this study that at all times 60,000 cubic feet of gas will be available as the dependable minimum per 24 hours for power generation purposes. This assumption is doubly conservative due to the fact that we have a reserve gas supply of approximately 45,000 cubic feet in storage under 6 inches water pressure. This reserve supply is held in our secondary digestion tanks, the upper portion of which are in reality single-lift gas holders. It becomes apparent that one of the prime requisites of a practical and successful sewage-gas engine installation is a gas holder having ample storage capacity to carry over during periods of lower-than-average gas production.

Hydrogen Sulphide and Its Removal

The presence of hydrogen sulphide (H_2S) in objectionable quantities in digester gas may prove injurious to the pistons and cylinder walls of gas

engines. While hydrogen sulphide itself is not seriously corrosive, its products of combustion, water and sulphur dioxide (SO_2) unite to form the highly corrosive sulphurous acid (H_2SO_3). The same products of combustion result from the presence in the gas of any form of sulphur; therefore, any volatile sulphide is just as objectionable in an engine fuel as is hydrogen sulphide.

Where the sulphide content of a sewage gas exceeds 0.07 percent by volume, or approximately 50 grains per 100 cubic feet, scrubbers should be used to clean the gas before it enters the engine. Sulphur as hydrogen sulphide may be removed by passing the gas through a bed of finely divided iron oxide and wood shavings. The iron oxide reacts with the hydrogen sulphide to form sulphide of iron and water, according to the following equation.

$$Fe_2O_3 + 3H_2S = Fe_2S_3 + 3H_2O$$

The wood shavings merely serve to keep the mass of iron oxide open, forming an "iron sponge," so that the gas can pass through without too much resistance.

At most sewage treatment plants, little or no trouble has been experienced due to hydrogen sulphide in the gas. Some plants, however, have found it necessary to first remove the sulphur. Several of these have installed a commercial type of scrubber, among them the plants at Peoria, Illinois, Fort Atkinson, Wisconsin, and Battle Creek, Michigan. The installation at Peoria is shown in Figure 4.

An inexpensive, home-made gas scrubber can constructed by following the design used at Galesburg, Illinois (3), as shown by Figure 5. It consists of a rectangular box providing a convenient depth of iron-sponge" and a perforated or slotted tray which carries the sponge. The tray is supported about three inches above the bottom of the box to permit the gas to be distributed over the entire area before passing upward through the sponge.

Since the chemical action between hydrogen sulphide and the iron oxide takes place more readily at temperatures above 60° F., the box should either be located in a warm place, or insulated, or provided with heating coils. It will be noted that the scrubbers shown in Figure 4 are provided with artificial heat. The inside of the box should be well coated with an asphaltic paint to prevent corrosion.

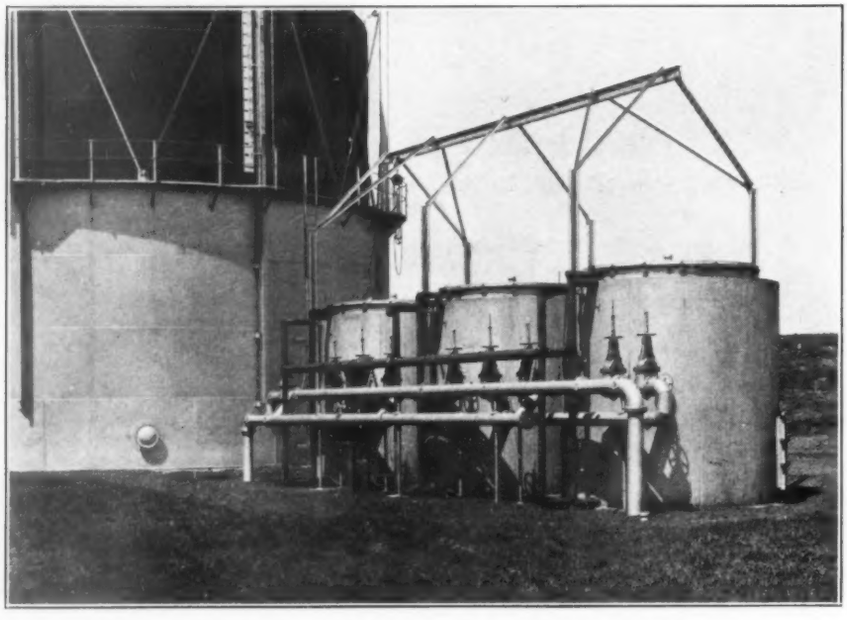


Fig. 4—Koppers Gas Purifiers and Gas Holder at Peoria, Ill.

The calculations for a gas scrubber for 80,000 c.f.d. of gas containing 100 grains H_2S per 100 cubic feet are as follows:

1. Sufficient "iron sponge" should be provided to last about 60 days.

2. 1 cu. ft. of sponge contains about 20 lbs. of ferric iron.

3. 20 lbs. of ferric iron will theoretically react with 127,000 grains of H_2S.

4. Practical considerations cut this figure to about one-third, or 40,000 grains of H_2S.

5. Average H_2S content in the gas under question is 100 grains per 100 cu. ft.

6. Total H_2S in 60 days = 100 x 800 x 60 = 4,800,000 grains.

7. Total quantity of "iron sponge" required is

$$\frac{4{,}800{,}000}{40{,}000} = 120 \text{ cu. ft.}$$

The useful life of the sponge may be extended by regeneration. If the exhausted (sulphided) sponge is *carefully* exposed to the air, the iron sulphide will absorb oxygen, enabling the iron to revert back to its original ferric oxide condition as follows:—

$$2Fe_2S_3 + 3O_2 = 2Fe_2O_3 + 6S$$

This reaction generates so much heat that the sponge may take fire and be ruined. However, rate of regeneration may be controlled by wetting the old sponge thoroughly with water, and then removing it from the box to a pile in the open air. When it has changed from a black to a dark brown color, it is again ready for use. "Iron sponge," thus regenerated, may be used two to three times before finally discarding.

When charging the box with sponge, care must be taken to pack uniformly. It should be lightly tamped several times while filling. Careful tamping around the sides of the box will prevent leakage of gas.

Engine Gas Supply

Most engine manufacturers will guarantee the fuel consumption at full load to be not in excess of 10,000 Btu. per BHPH. This is equivalent to 15,000 Btu. per KWH. For a sewage gas having a low heat value of 575 Btu. per cubic foot, the consumption will be

$$\frac{15{,}000}{575} = 26.1 \text{ cu. ft./KWH}$$

At other loadings, the fuel requirements will be approximately as follows:—

1/2 Load—32.7 cu. ft./KWH
2/3 Load—29.3 cu. ft./KWH
5/6 Load—27.5 cu. ft./KWH

The total daily engine gas consumption shown in Table 3 was computed on the basis of using one engine up to 60 KW demand, and above 60 KW demand using both engines in parallel, each taking one-half the total load.

The sewage gas is introduced into the engine through a gas mixing-valve which mixes the gas with atmospheric air in the proper proportions. The function of this valve is similar to that of a carburetor on a gasoline engine. It should contain an air valve and a gas valve, each separately regulated in order that the fuel mixture may be changed to suit the varying Btu. content of the sewage gas.

The gas pressure ahead of the mixing valve should be reduced by means of a suitable pressure regulator to atmospheric pressure. To insure a constant supply of gas at atmospheric pressure at all times, a gas reservoir is usually installed between the mixing valve and the pressure regulator. The size of this reservoir depends upon the engine rating, but should not be less than about 30 cubic inches per horsepower.

Heat Recovery

(a) From Jacket Water

In most cases where sewage gas is being used for power, part or all of the waste heat from the engine is recovered for the heating of digestion tanks and buildings. If this were not done, the heat normally derived from the gas would have to be replaced by other fuels, such as coal or oil. Such an arrangement would probably prove economically unsound. Therefore, if gas is used for power purposes, no additional heating cost should be incurred, and such heat as may be required should be obtained from the engine waste heat, and from the excess gas.

The heat consumed in a gas engine, the heat wasted, and the heat which is recoverable depend upon the type of engine. For a 90 HP., four-cycle, slow-speed engine operating under full load, a typical heat balance is as follows:—

Heat going to useful work 25.5%
Heat to radiation 3.5%
Heat to jacket cooling water....33.5%
Heat to exhaust and friction....37.5%

Of the above heat, all of that carried away by the jacket cooling water can be recovered by connecting the jacket water piping into the hot water heating system. For best operating conditions, the cooling water should enter the engine at between 110°F. to 130°F., and should leave the engine at between 140° F. to 160° F. Approximately 3300 Btu./-BHPH must be removed from the engine jacket water to ensure efficient cooling. Therefore, if the engine jacket water is passed through the digestion tank heating coils, these coils, acting as a water cooler, must be able to extract this amount of heat from the jacket water both winter and summer. If not, all or part of the jacket water must be circulated through a separate water cooler.

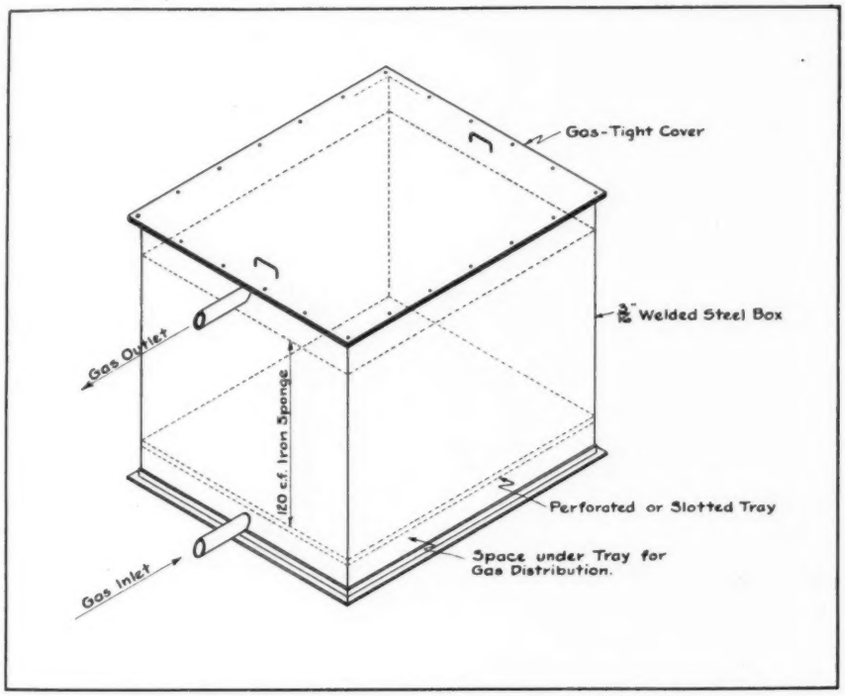


Fig. 5—Home-Built Sulphide Scrubber, at Galesburg, Ill.

For a 90 HP engine operating at full load the heat recoverable from the jacket water is therefore

$$3300 \times 90 = 297{,}000 \text{ Btu/hr.}$$

The amount of jacket cooling water required for a 30° F. temperature rise will be

$$Q = \frac{3300 \times 90}{30\ (^\circ\text{Temp. diff.}) \times 8.34} = 1190 \text{ gph.}$$

In the jacket water system, therefore, we must provide a cooler (digestion tank or other) to extract the necessary heat from the water. We have calculated that a circulating water pump of at least 20 gpm (1190 gph) capacity will be required to ensure positive water circulation. A vented surge tank should be installed at the high point of the jacket water system, either between the engine outlet and the cooler, or just ahead of the circulating pump. Thermometers should be provided at the cold water inlet and the hot water outlet.

(b) From Exhaust Gas

A portion of the heat normally carried away by the exhaust gases is recoverable. The quantity recovered is governed by practical limitations in the size of the waste heat boiler, and also by the lower temperature limit to which gases can be safely cooled without condensation and the consequent corrosion of the surfaces with which they come in contact.

The importance of avoiding condensation of the moisture contained in the exhaust gases cannot be too highly stressed. The point of condensation, often called the dew point, has been found to be about 130° F. However, an exhaust gas temperature slightly higher than 130° F. is not sufficient to avoid condensation, due to the fact that exhaust gas temperatures drop very sharply when they come in contact with surfaces having a water temperature below 130° F.

This sudden temperature drop is due to the inability of the gas film adjacent to the heating surface to transmit the heat from the main body of the gases to the water quickly enough. The resistance offered by the gas film causes the moisture in the gases to condense on the cold surfaces even though the main body of gases are at temperatures far above the dew point. Hence it is obvious that the water inlet temperature should not be less than 130° F., and the lower temperature limit of the main body of the exhaust gas should be well above the dew point. Experience has indicated that 300° F. is a safe minimum exhaust gas temperature.

Where 130° F. water is not available, the ideal method of reclaiming waste heat is by means of a waste heat boiler generating low pressure steam. The steam generated therein is delivered to an independent tubular heater through which water passes in the tubes. When the steam condenses in the independent heater, the condensate returns by gravity to the waste heat boiler where it is again evaporated. In this manner the cycle is closed and the water temperature remains well above 130° F., except for short periods when starting up after long shut downs. Nevertheless, practically all condensation with its consequent corrosion is eliminated.

At Rahway we have decided upon a waste heat boiler which will extract

sufficient heat to cool the gas from 900° F. to 300° F. at full load. Obviously, at fractional loads, the final gas temperature will be under300° F. due to the lower initial temperature and smaller gas quantities, but at low loads it will still be above the dew point. As a further precaution against corrosion, the cooling water will first be circulated through the engine jackets as the cooling medium for the engines. In so doing, the water will be preheated from 110° F. to 140° F. before entering the waste heat boiler. This double precaution against the possibility of a highly corrosive condensate appears to be the best guarantee for the long life of the equipment, and for low maintenance costs.

A waste heat boiler is shown by

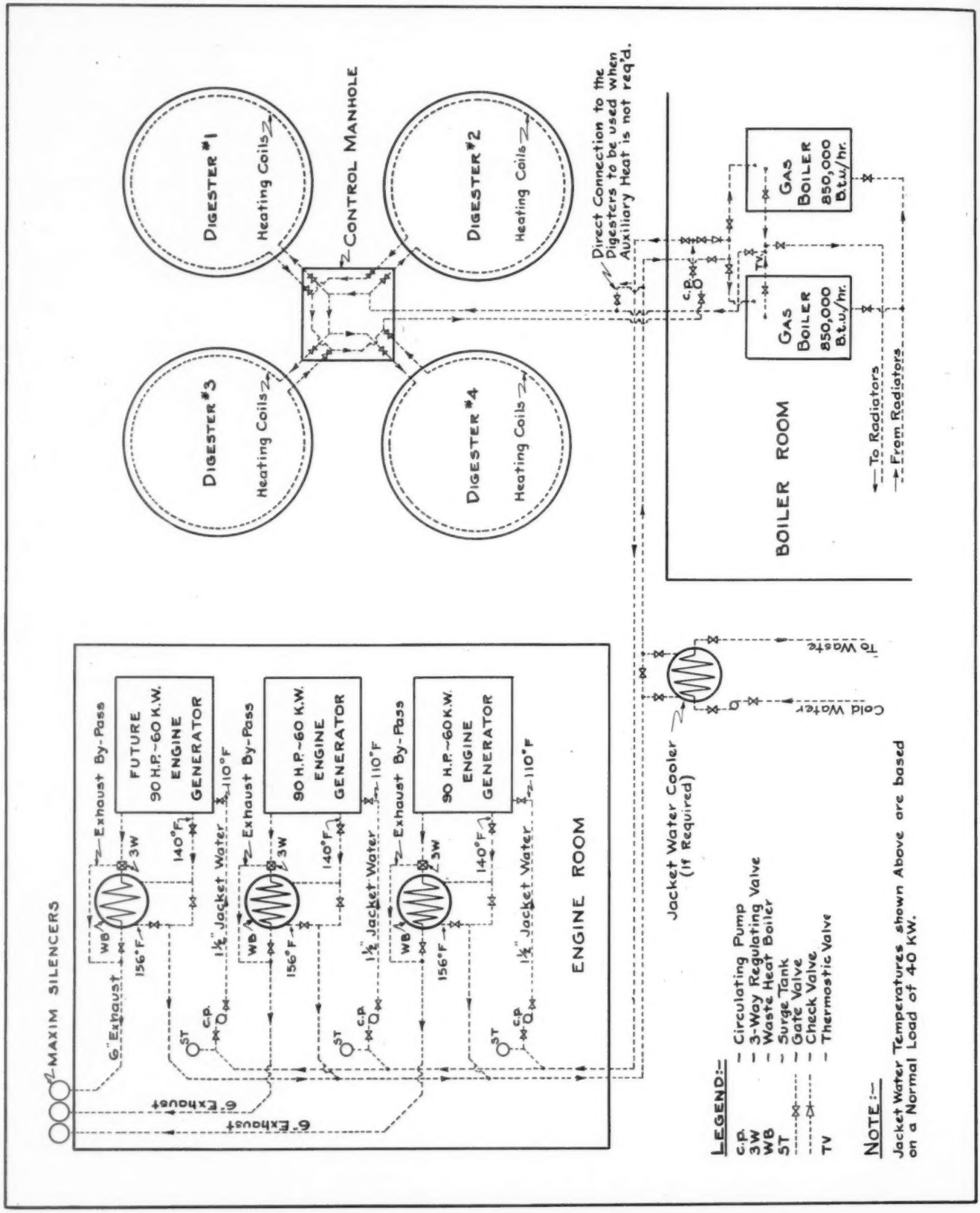


Fig. 6—Heat Exchange Diagrams Developed for the Rahway Valley Plant

Figure 7. It is a shell and tube type of boiler, the exhaust gases being passed through the boiler tubes, and the heat being absorbed by the cooling water which completely fills the shell and surrounds the tubes. The exhaust gases, cooled down considerably by the boiler, pass on out to atmosphere. The waste heat boiler itself will also serve as a silencer, no further silencing being necessary. Where a by-pass around the boiler is provided, a suitable silencer should be installed on the by-pass line. The arrangement proposed at Rahway will make it possible to by-pass all or a part of the exhaust gases around the boiler by means of a 3-way regulating valve. The piping is also so arranged that the jacket water can be by-passed around the waste heat boiler.

A pyrometer will be provided with a sufficient number of thermocouple selection points to permit temperature readings of the exhaust gas to be taken at each cylinder, and at the discharge from the waste heat boiler.

Naturally, the amount of heat going into the exhaust gas depends upon the bore and stroke, number of cylinders, speed and type of engine. A four-cycle engine with water-cooled exhaust manifold will produce exhaust gases having temperatures of from 800° F. to 900° F., while the exhaust gases from a two-cycle engine will probably range from 300° F. to 500° F.

A typical range of exhaust gas quantities and the corresponding temperatures for a 90 HP., four-cycle engine operating under several loadings is shown below. This data must be obtained from the manufacturer of the engine to be used.

	Exhaust Gas Quantity	Temperature
1/2 Load	683 Lbs./hr.	850
2/3 Load	845 Lbs./hr.	866
3/4 Load	918 Lbs./hr.	875
5/6 Load	994 Lbs./hr.	883
Full Load	1130 Lbs./hr.	900

Obviously, the quantity of heat which may be extracted from the exhaust gas depends upon the difference between the initial and final temperatures, and the specific heat of the gas. The specific heat of the exhaust gas from a gas engine will be about 0.24, this representing the ratio of the heat required to raise one pound of the gas 1° F., to the heat required to raise one pound of water 1° F. Therefore, the heat recoverable from the exhaust gas of a 90 HP., four-cycle engine operating under full load will be

$$1130 \text{ lbs/hr.} \times (900° - 300°) \times 0.24 = 162{,}720 \text{ btu/hr.}$$

(c) From Engine Radiation

The heat radiated from the engines (about 3.5%) cannot be transferred to the hot water heating system, but it does assist in the heating problem by partially heating the engine-room, thus relieving the heating system of this portion of the total heating load. Generally speaking, the radiation losses at the engine will be from 2 percent to 4 percent of the total heat input.

Heat from Excess Gas

At Rahway we have at present a hot water heating plant which heats the digestion tanks and all buildings.

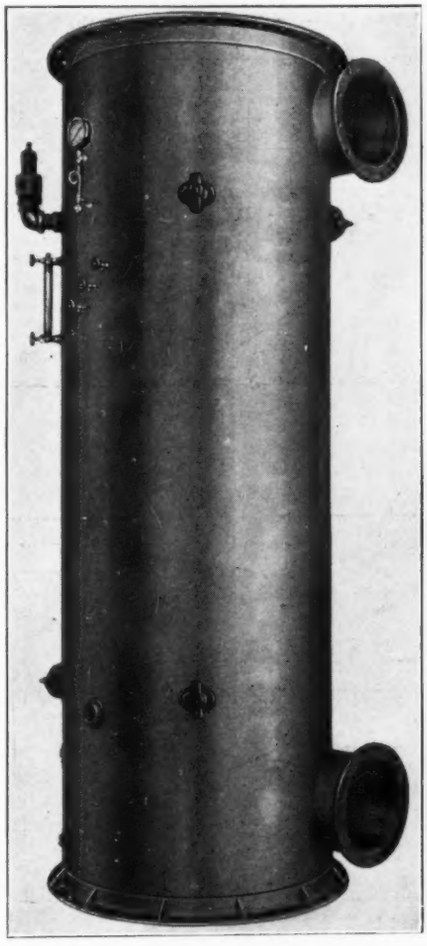


Fig. 7—Davis "Paracoil" Waste Heat Boiler

The boilers are operated exclusively on sewage gas. The Heat Exchange Diagram shown in Figure 6 shows how the heated water from the engine-room will be run directly into the return line at the bottom of the boilers, and circulated through the boilers where the temperature will be raised to the desired degree. The return water to the engines will be taken from the digestion tank return water, which averages about 110° F. In using the boilers to "jack-up" the temperature of the heating water, we must rely on the sewage gas which may be left over after all engine requirements have been satisfied. Since the boiler efficiency approximates 68 percent, the boiler heat output which is available when one engine is operating under a 60 KW demand will be

$$\frac{22{,}500 \times 650 \times 0.68}{24} = 415{,}000 \text{ btu/hr.}$$

This is shown in Table 3.

Thus it is apparent that the system will be extremely simple and yet highly flexible. The combined heat from the exhaust gases and the jacket cooling water can be used to heat the digestion tanks in summer, and to aid in the heating of tanks and buildings in the winter. Exhaust gas heat can be recovered, or it can be by-passed as desired. Since our average power load is 40 KW, it can be seen that sufficient heat is available to meet all normal winter heating requirements.

Construction and Operating Costs

Estimate of Cost

Two 90 HP.—60KW—100 KVA heavy-duty gas-engine generator sets, complete with gauge boards, gas reservoirs, Maxim silencers, exhaust gas pyrometers, electric alarm and shut-down systems, water circulating pumps, starting air equipment, gasoline carburetors, and installation	$19,000.00
Two Waste Heat Boilers	660.00
Two 3-Way Regulating Valves	240.00
Generator panels, with ammeters, voltmeters, wattmeters, frequency meters, voltage regulators, field rheostats, synchroscope	2,340.00
Distribution Panel, Electric Wiring and Lighting	1,600.00
Station Piping	1,000.00
Outside Piping	3,500.00
Building (29′ x 39′ x 15′)	6,000.00
1½ Ton Crane and Hoist	450.00
Engine Foundation (3 Engines)	800.00
Gas Meter	400.00
Contingencies	1,200.00
Total Estimated Construction Cost	$37,190.00
Legal, Administrative, etc.	3,000.00
Total Estimated Cost	$40,190.00

Amortization and Operating Costs

Gas engines, when on continuous service, are generally conceded to have a useful life of from 15 to 20 years. With two engines, each capable of carrying the normal load, the service is divided. Hence, the life of each engine may be conservatively set at 20 years.

By looking back at Table 1, it will be seen that in most cases the cost

of additional labor to operate and maintain the engines is negligible. In fact, a number of the replies indicated that no additional labor cost was incurred.

Experience on the cost of repairs and lubricating oil seems to differ widely. A fair allowance for repairs is $2.00 per BHP per annum. This figure is somewhat higher than the engine manufacturers themselves predict on the basis of their own experience, and is thus felt to be sufficiently conservative for the purpose of this analysis.

Lubricating oil at most plants amounts to about 1 gallon for 2000 BHPH. However, oil consumption can be reduced somewhat by the use of oil refiners. At the Rahway plant, we estimate a total of 335,000 KWH per annum, which is equivalent to 500,000 BHPH. Our oil consumption, therefore, is expected to be approximately 250 gal.

Annual Charges and Savings

Interest on Investment @ 4%	$1,607.60
Amortization of Engine— $\frac{1}{20}$ x $21,300	1,065.00
Amortization of Miscellaneous Equipment— $\frac{1}{25}$ x $6,400	256.00
Amortization of Permanent Structures and Piping— $\frac{1}{30}$ x $12,490	416.33
Repairs—57 BHPH/annum @ $2.00	114.00
Lubricating Oil—250 gallons @ 12c	30.00
Estimated Annual Cost	$3,488.93
Present Annual Power Cost*	5,700.00
Net Annual Saving (based on present power cost)	$2,211.07

*Our purchased power cost will increase from year to year as the sewage load increases, hence the savings will likewise increase.

References

(1) W. B. Walraven "Development of Power from Sewage Sludge Gas," Sewage Works Journal, Vol. 4, Page 614 (July, 1932). "Experience with Gas Engine Operation — During Three and One-Half Years of Use," Water Works & Sewerage, p. 370, Vol. 83 (October, 1936). Water Works & Sewerage, p. 151, Vol. 80 (May, 1933).

(2) W. A. Sperry "Gas Engine Installation—Aurora, Illinois,' Water Works & Sewerage, Page 11, Vol. 84 (January, 1937) and Page 327, Vol. 84 (September, 1937).

(3) L. W. Hunt, Chief Chemist, the Galesburg Sanitary District—by letter.

TABLE 1. TABULATION OF DATA ON POWER GENERATION FROM SEWAGE GAS
(Taken from replies to questionnaire)

Location	Pop. Served	Total H.P.	Make of Engine	Gas Production c.f.d.	Gas Consumption cu. ft.	Net Annual Savings	Annual Repairs	Annual Lubric. Oil	Additional Annual Labor Cost
Battle Creek, Mich.	36,300	60	Le Roi	59,000	8/BHPH	$2,004	$ 55	$ 90	None
Los Angeles, Cal.	374,000	450	Clark	250,000	24/BHPH	4,600	100	325	None
Green Bay, Wisc.	40,000	210	Worthington	40,000	26/KWH	2,835	96	189	$234
Cedar Rapids, Iowa	55,000	200	Worthington	147,760	15/BHPH	6,000	300	700	275
Janesville, Wisc.	20,000	30	Worthington	25,000	17/BHPH	850	600	110	150
Grand Rapids, Mich.	178,000	150	Buda	138,000	——	1,000	15	30	30
Fort Atkinson, Wisc.	6,000	15KVA	Le Roi	75,000	24/Kwh	1,950	300	75	None
Richmond, Ind.	28,000	120	Worthington	25,000	9.5/BHPH	6,000	None	200	None
Ann Arbor, Mich.	40,000	120	Worthington	50,000	15/BHPH	6,000	None	170	None
Topeka, Kans.	50,000	360	Worthington	Ample	——	5,400	200	425	——
Aurora, Ill.	49,000	140	Climax	49,500	21.8/BHPH	*	219	88	None
Kokomo, Ind.	36,000	45	Worthington	15,000	19/BHPH	1,800	None	55	None
Toledo, Ohio	60,000	535	Rathbun	250,000	9500Btu/BHPH	13,299	382	576	None

*Plant operating cost reduced 20%.

TABLE 2. GENERAL DATA ON POWER, GAS PRODUCTION, AND HEAT REQUIREMENTS
(As determined for the Rahway Valley Plant)

Month	Hourly Rates of Power Consumption			Max. Demand from Demand Chart	Gas Production		Heat Requirements				
							Digestion Tanks				
	Max. Day KWH	Min. Day KWH	Monthly Aver. KWH	KW	Average c.f.d.	Maximum c.f.d.	Aver. Circ. Water g.p.h.	Temp. Diff. °F	Heat Req'd Btu/hr.	Heating of Buildings	Total Heat Required Btu/hr. Btu/hr.
January	80	23	35	99	63,000	85,000	3,600	18	540,000	400,000	940,000
February	57	30	39	70	68,000	86,000	3,400	17	485,000	400,000	885,000
March	73	33	42	78	67,000	86,000	3,620	21	635,000	350,000	985,000
April	60	30	39	76	72,000	89,000	3,500	23	670,000	200,000	870,000
May	37	27	31	50	61,000	79,000	3,250	19	516,000	75,000	591,000
June	60	23	32	51	73,000	87,000	2,780	23	535,000	0	535,000
July	113*	27	43	119*	72,000	85,000	3,480	13	377,000	0	377,000
August	40	27	35	72	70,000	81,000	3,400	16	453,000	0	453,000
September	114*	27	39	124*	85,000	104,000	3,100	15	387,000	0	387,000
October	40	27	37	60	78,000	103,000	3,250	17	462,000	80,000	542,000
Average					71,000						

*Exceptionally Heavy Storms.

TABLE 3. FUEL AND HEAT BALANCE

Daily Load	Engine Gas Consumption		Excess Gas*	Boiler Heat Available from Excess Gas**	Recoverable Heat		Radiation from Engines		Total Heat Available	Aver. Heat Req'd during Winter Months	Max. Heat Req'd for a Zero Day
					From Jacket Water	From Engine Exhaust	%	Heat			
KWH	Btu/KWH	c.f.d.	c.f.d.	Btu/hr.	Btu/hr.	Btu/hr.	Loss	Btu/hr.	Btu/hr.	Btu/hr.	Btu/hr.
80	16,800	56,000	4,000	74,000	396,000	238,000	2¼	30,000	738,000	850,000	1,070,000
70	17,600	51,200	8,800	162,000	345,000	216,000	2½	34,000	757,000	850,000	1,070,000
60	15,000	37,500	22,500	415,000	297,000	163,000	1½	15,000	890,000	850,000	1,070,000
50	15,800	33,000	27,000	495,000	248,000	138,000	2	17,000	898,000	850,000	1,070,000
40	16,800	28,000	32,000	590,000	197,000	119,000	2¼	16,000	922,000	850,000	1,070,000
30	18,800	24,000	36,000	660,000	149,000	95,000	2½	16,000	920,000	850,000	1,070,000

*Daily Average Gas Production to be expected is 60,000 c.f.d.

**Hot Water Boiler Efficiency estimated at 68%.

NOTES:

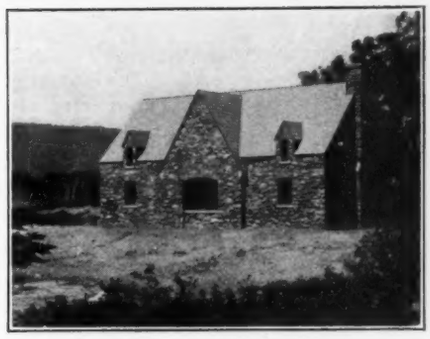
High heat value of sewage-gas = 650 Btu; low heat value = 575 Btu.

Fuel requirements and heat recovery, based on the following:

Engine—Worthington 90 HP.—60 K.W. Type BG-3.

Waste Heat Boiler—Davis Paracoil N-70.

WATER HAMMER



Chazy Lake Station

Experiences at Chazy Lake Pumping Station and Correction of Trouble

By HENRY RYON
Senior Sanitary Engineer
N. Y. State Dept. of Public Works
ALBANY, N. Y.

The Author

IN ORDER to provide water for Clinton Prison at Dannemora, N. Y., it was found necessary to use Chazy Lake as a source of supply and to lift the water over Dannemora mountain to the prison reservoir. This required the installation of a pumping station and a force main about 4½ miles long with a rise of 530 feet. The pumping station and pipe line were put in operation late in 1932, and almost immediately trouble was experienced due to the failure of the lead joints in the pressure line. The cause of these failures was apparently the high pressures developed when the pumps were stopped, and studies were made to determine the best method of reducing these high pressures.

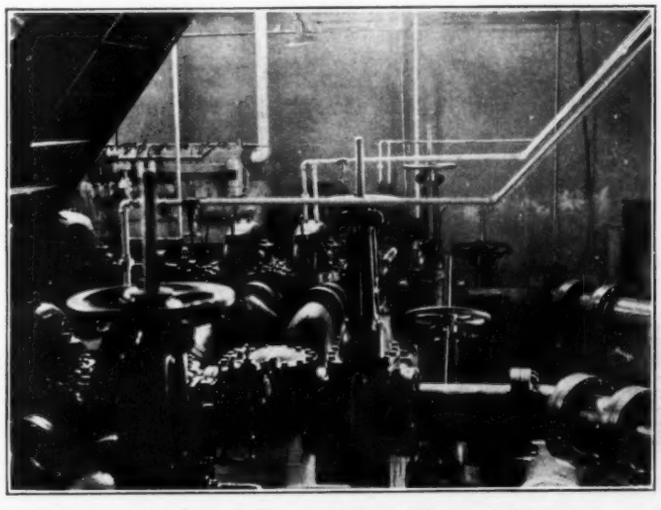
Installation

The pumping equipment consists of two electrically driven four-stage centrifugal pumps each having a capacity of 390 gallons per minute against a head of 619 feet. The pumps are set approximately at normal lake level. The suction line is of 10-inch cast iron pipe and is about 400 feet long. The discharge main is of 8-inch cast iron bell and spigot pipe, Class G to Class B, and is 23,720 feet long. The static head at the pumps is 530 feet, the equivalent of approximately 230 pounds per square inch. There is a standard swing check valve on the suction line and a similar check on the discharge line of each pump. A 6-inch spring loaded relief valve and an air chamber 8 inches by 96 inches in size were provided on the main discharge line near the pumps.

Line Pressures

In order to study the pressures in the discharge line a recording pressure gauge with a fast moving chart was connected to the line just beyond the relief valve. A typical pressure curve plotted by this gauge with one pump in operation and the relief valve and air chamber shut off is shown in Fig. 1.

The static pressure is 230 pounds per square inch. When one pump is started the pressure gradually rises to 310 pounds per square inch, the rise for each of the four steps of the starter showing distinctly, and then drops to the running pressure of 275 pounds per square inch. When the pump is stopped the pressure drops very quickly from 275 pounds per square inch to 90 pounds per square inch and then rises to 370 pounds per square inch. These subnormal and supernormal pressures continue at regular intervals, the variations above and below the static pressure becoming less and less as line friction gradually damps them out. The time of one complete cycle is 23.1 seconds, and since the water-hammer wave must travel four times the length of the pipe in one cycle, its velocity is at the high speed of 4,110 feet per second. By comparison, the maximum velocity of flow in the pipe, with one pump in operation, is only 2.49 feet per second.



Interior of Pump Room—Chazy Lake

It is, of course, the first super-normal pressure wave that causes most of the damage to the pipe line. The subnormal pressure wave cannot, however, be neglected for it very definitely limits the amount of air that can be retained in the air chamber.

Water Hammer Waves

In order to explain the method evolved to control the water-hammer pressures, it is necessary to

consider first the nature of a water-hammer wave. The magnitude and velocity of the wave depend upon the elasticity of the material composing the pipe wall, the velocity of the water in the pipe and the time in which that velocity or part of that velocity is extinguished. They are independent of pressure in the pipe and causes the water in this first section to expand, the pressure to fall and the pipe to contract. In other words, the kinetic energy of the moving water has been converted into potential energy. The water in the first section being at rest or static, the velocity of the water in the second section must necessarily cease. The

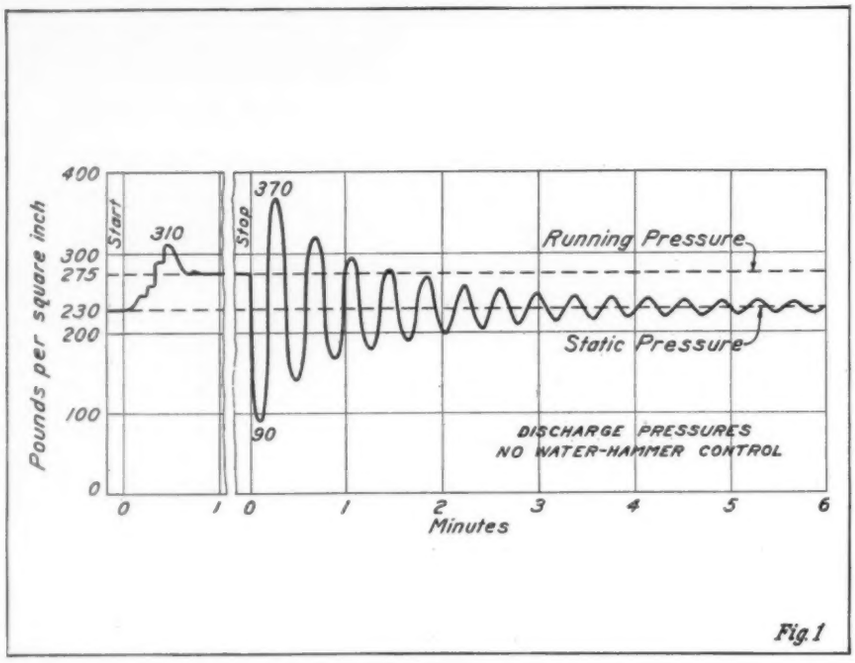


Fig. 1—Typical Pressure Wave Graph
(One pump thrown out; relief valve and air chamber shut off at the time)

flow velocity, except that part of the velocity that is extinguished. The water-hammer pressure or excess pressure is the variation above or below normal caused by the water-hammer wave. In this case (and in other cases where conditions are similar) the momentum of the rotating parts of the pump and motor is so small in comparison with the load that when the switch is opened the pump ceases to deliver water almost instantly. The suction line being short, no high pressure of any duration is developed in it that might force water through the pump. As a result the stopping of the pump has for all practical purposes the same effect as almost instantaneously closing a valve.

An Analysis

This effect can be examined best by considering the pipe line to be divided into a large number of very small sections of equal length.

When a valve at the inlet end of a pipe in which water is flowing is instantaneously closed, the velocity of the water in the section adjacent to the valve (in this case the pump), is immediately extinguished. This water in the second section then expands, the pressure falls and the pipe contracts in the same manner as in the first section. This reduction in pressure in the second section in no way affects the pressure in the first section for the pressure in that section, excepting gravity and friction, is dependent entirely upon the destruction of the kinetic energy of the water in that section. And, the kinetic energy of the water in the second section is exactly the same as that of the water in the first section and its destruction therefore produces exactly the same reduction of pressure. This process continues through the third, fourth and other sections of the pipe until all the water in the line has expanded, the entire pipe line contracted and the pressure throughout fallen by the same amount. The wave has traveled the length of the pipe once and the water is at rest.

This condition, however, is not stable. The water in the lower end of the pipe cannot move, but the water in the upper end is free to contract. This it does immediately. The water in the upper section contracts, the pressure rises and the pipe expands. As a result of this contraction of the water and the expansion of the pipe in the upper section, water flows into the pipe. Conditions in the upper section having thus changed, the second or adjacent section is free to move. The water in the second section then contracts, the pressure rises and the pipe expands. This draws more water into the pipe. In a like manner similar changes occur in the third, fourth and other sections until all the water in the line has again contracted, the entire pipe line expanded and the pressure throughout risen to the point (excepting friction at which it was before the valve was closed or the pump stopped. The wave has traveled the length of the pipe twice.

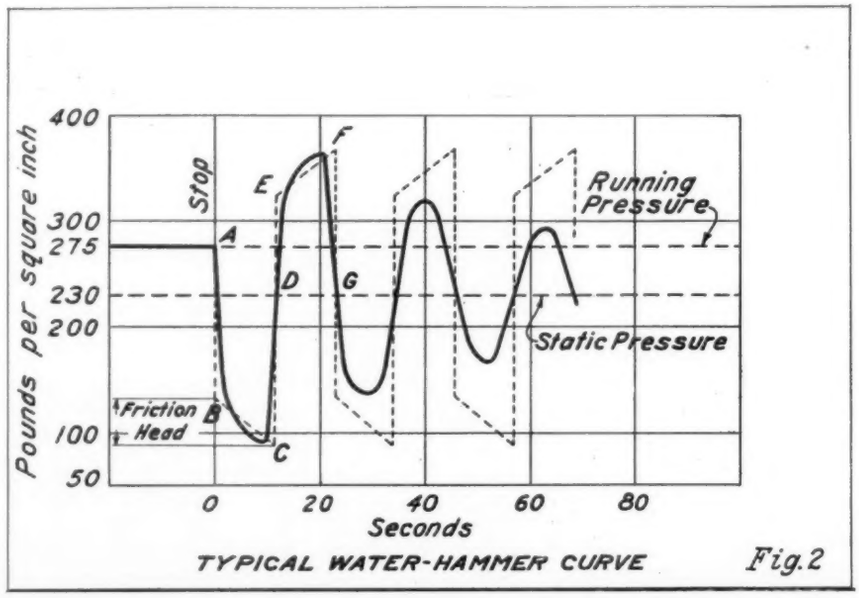


Fig. 2—Graph of Wave Near the Pump
(Explanation of significance in text)

The water is in motion and is flowing toward the pump with the same velocity, excepting for friction losses, at which it was flowing away from the pump before the pump was stopped.

This flow cannot continue, for while the wave has been traveling twice the length of the pipe, ample time has elapsed (11.5 seconds in this case) for the check valve at the pump to close tightly. The flow is therefore directed toward a closed valve and the velocity in the first section adjacent to the check valve is instantly extinguished. The water in this section is compressed, the pressure rises and the pipe expands. The water in the first section being at rest, the water in the second section must necessarily come to rest with the same changes in condition as occurred in the first section. In a like manner, the water in the third, fourth and other sections come to rest successively until all the water in the pipe line is at rest and compressed, the pressure above normal and the pipe expanded for its entire length. The wave has traveled three times the length of the pipe and the water is once more at rest.

Again, however, the conditions are unstable. The water in the lower end of the pipe cannot move but that in the upper end is free to expand. This it does immediately. The water in the first section expands, the pressure falls and the pipe contracts causing water to flow out of the upper end. Conditions having changed in the upper or first section, the second section is free to move. The water in the second section then expands, the pressure falls and the pipe contracts causing a further flow of water out of the upper end of the pipe. Similar changes occur in the third, fourth and other sections of the pipe until all the water in the pipe has expanded, the entire pipe line contracted and the pressure (except for friction losses) fallen to the normal running pressure. The wave has traveled the length of the pipe four times. The water is moving away from the pump with the same velocity, excepting friction losses, that it was before the pump was stopped. In other words, one cycle has been completed, and conditions are the same as when the pump was running.

The cycle repeats itself until the friction gradually damps out the wave.

A diagram of the effect of this wave near the pump is shown in Fig. 2. The complete cycle is from A to G. The slope of the line from B to C is due to the fall in friction pressure as the wave passes up the pipe and the water gradually comes to rest. The slope from E to F is due to the rise in friction pressure as the velocity away from the pipe is gradually regained.

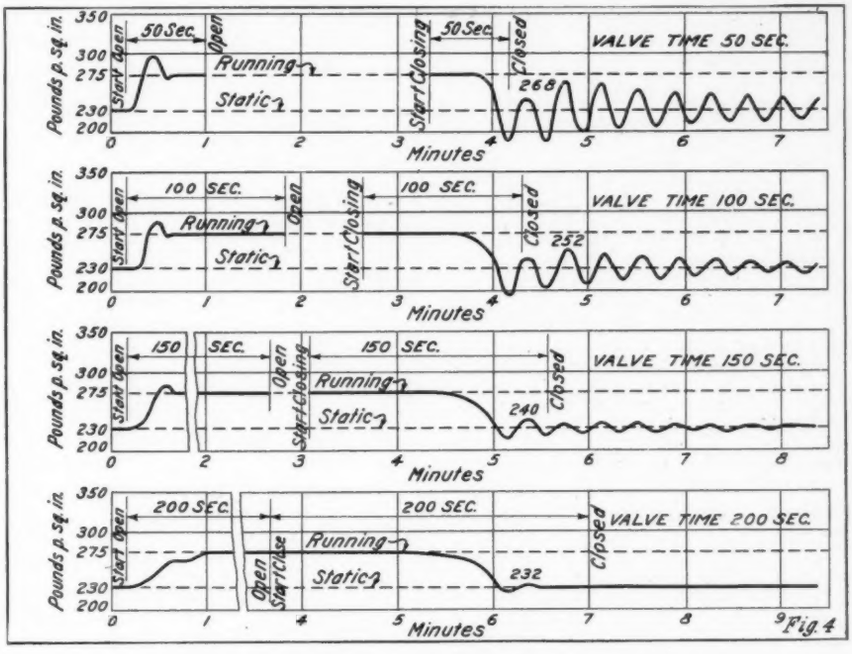


Fig. 4—Graph Showing Results With a Cone Valve

The value of studying the effects of various closure times for surge suppression is effectively revealed in the four recorded graphs. A splendid testimonial as to the efficacy of properly controlled cone valves

A comparison of the velocities and pressures as observed and those computed by Joukovsky's formula (Proceedings, Am. Water Works Assoc., 1904, p. 341) (W. W. and S., April, 1938, p. 338) is interesting.

Joukovsky's formula for water-hammer, produced by instantaneous valve closure, is:

$$H = \frac{aV}{g}$$

$$a = \frac{12}{\sqrt{\frac{w}{g}\left(\frac{1}{K} + \frac{D}{Ee}\right)}}$$

H = Head due to water-hammer, ft.
a = Velocity of water-hammer water, f.p.s.
V = Velocity of water in pipe, f.p.s.
g = Acceleration of gravity.
w = Weight of one cubic foot of water.
K = Bulk modulus of elasticity of water, pounds per sq. in.
E = Modulus of elasticity of pipe material, pounds per sq. in.

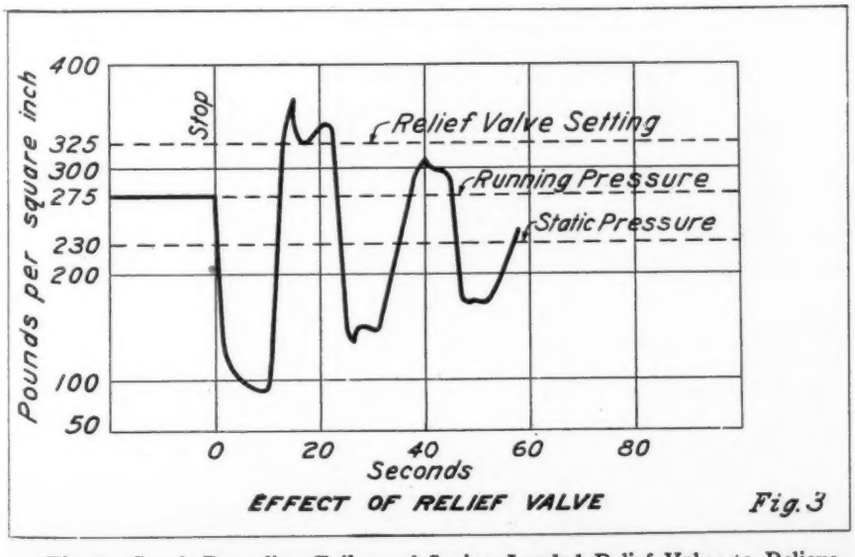


Fig. 3—Graph Revealing Failure of Spring Loaded Relief Valve to Relieve

D = Diameter of pipe, inches.
e = Thickness of pipe wall, inches.

The results are as follows:

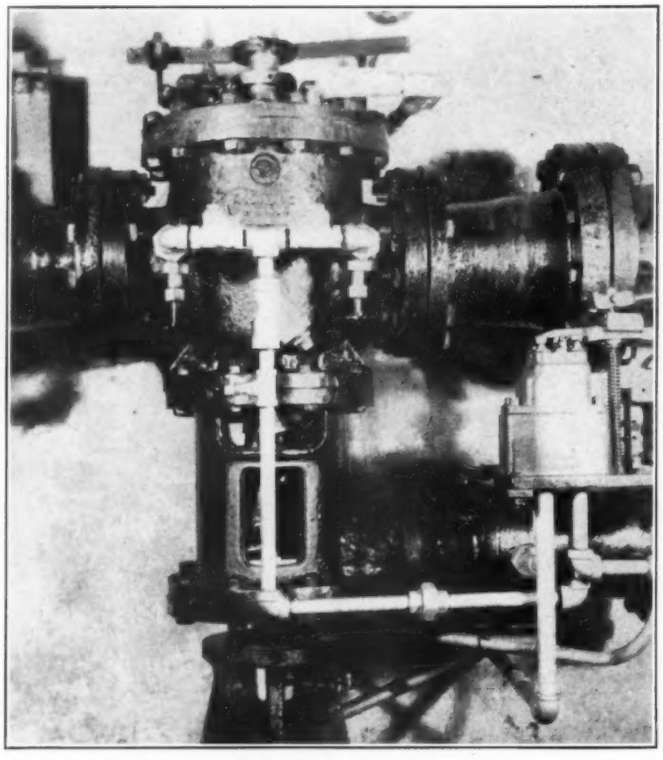
Computed water-hammer head (negative) .....326 ft.
Observed water-hammer head (negative) .....322 ft.
Computed velocity of water-hammer wave .....4220 f.p.s.
Observed velocity of water-hammer wave .....4110 f.p.s.

If the pipe line had been shorter or the time of stopping longer so that the water-hammer wave set up by the first reduction in the discharge of the pump could have traveled to the end of the pipe and returned to the pump before the flow through the pump had stopped the returning supernormal wave would have interfered with the subnormal wave and the magnitude of the wave would have been reduced. So long as the returning wave does not reach the pump until its discharge is entirely stopped $\left(t < \frac{aL}{2}\right)$ the result, for all practical purposes, is the same as that produced by an instantaneously closed valve. If it does return before the pump discharge has ceased, the interference of the waves must be considered. Except for this interference, the *water-hammer pressure is independent of the length of the pipe.* In the suction line which is only 400 feet long, the first wave returns in 0.2 of a second and interferes with the following waves, preventing, as stated before, the development of a pressure in the suction that might force water through the pump.

Relief Valves

When the Chazy Lake pumping station was built, a 4-inch spring loaded relief valve was installed on the 8-inch discharge line for the purpose of preventing any undue rise in pressure. This relief valve failed to produce the desired result. The effect of the relief valve on the water-hammer pressures shown in Fig. 3. The inertia of the moving parts in the valve apparently prevents it from opening rapidly enough to relieve the pressure and the head rises almost to the same value that it does without the valve in operation. When it finally does release the water the pressure falls to that for which the valve is set. The valve then closes and stops the flow of water through it. The stopping of this flow sets up another water-hammer wave and the pressure again rises.

In order to satisfactorily prevent high pressures by means of a relief valve, the valve must open *before* the first returning wave reaches the pump. That is, before the pressure reaches the point D in Fig. 2. At this time the water in the line is flowing toward the pump and the pressure is the normal static pressure. If the valve is open at this time the water will flow out of the valve with no material rise in pressure. The valve must close slowly or the stopping of the flow through the valve will set up another water-hammer wave with consequent high pressures. It is generally necessary to provide an auxiliary source of power if this method of preventing high pressures is used because the pressure in the line is subnormal at the time the valve must start to open and usually insufficient to operate any type of valve.



The Cone Valve
Which, with proper setting for closing time, has solved the water hammer problem

This arrangement is used effectively at the Dalecarlia Pumping Station, Washington, D. C. (Water Works and Sewerage, April, 1938, Page 353)*. In this case the relief valve is of the hydraulically operated rotary plug type and the power for opening it is obtained from an independent water main near the station.

Air Chambers

The 8-inch by 96-inch air chamber provided on the discharge line from the pumps was found on test to be of absolutely no value in reducing the water-hammer pressures, and computations by the graphic method of Prof. Angus indicated that no reduction could be expected. An air chamber on the discharge line of a pump acts by supplying water to the line in gradually decreasing quantities after the pump has stopped, causing a gradual reduction in the velocity in the line instead of a sudden one. That is, it produces an effect similar to that of a slowly closed valve.

To prevent high pressures in a pipe line by closing a valve slowly instead of rapidly requires that the time of closing be considerable, and if an air chamber is to be effective it must supply water to the line for a considerable time. Not only must the air chamber be large enough to contain sufficient water to maintain this supply over the necessary period, but there must be sufficient air above the water to maintain the proper pressure on the water as the air expands. Air chambers, if they are to produce any measurable effect, must be far larger than those usually provided and often so large as to be impractical. Tests are now being conducted at the pumping station of another institution to determine the effects of air chambers of different sizes, but the results must await later publication.

Cone Valve in Discharge Solves the Problem

The method now used at the Chazy Lake pumping station to eliminate the high water-hammer pressures is to reduce slowly the velocity in the discharge line before the pump being used is stopped—this instead of allowing velocity to be suddenly extinguished by the stopping of the pump. This is accomplished by a 6-inch hydraulically operated cone valve located in the main 8-inch discharge line near the pumps (see picture). The cone valve is in closed position

*Also see Reference and Data Section of this issue which contains the article.

when the pump is started. Since a centrifugal pump requires the smallest amount of power when operating against a closed valve, the motor thus starts under minimum load. As soon as the pump reaches its normal speed the cone valve slowly opens, the time of opening being controlled by the setting of a needle valve on the water feed-line to the hydraulic cylinder operating the cone valve. When it is desired to stop the pump the cone valve is first closed slowly, gradually reducing the velocity in the discharge main. After the valve is entirely closed the pump is stopped in the ordinary manner. Electrical interlocks are provided so that the attendant cannot change the order of the operations.

Results

The results of this method of operation, for different timings of the valve, are shown in Fig. 4. This valve rises from its seat before turning and reseats itself after completing its rotary motion. The time given for opening and closing is the time taken for the valve to rotate through 90 degrees, and does not include the time taken for unseating and seating. There is some leakage past the plug when it is raised from its seat, and the stoppage of this leakage by the seating of the valve in some cases causes a slight secondary wave, as is noticeable in some of the curves. The destruction of the velocity in the pipe line is, of course, not proportional to the amount of rotation of the valve as is evident from the fact that the first 2/3 of the revolution produces no measurable effect on the pressure. The effective closing time is therefore only a fraction of the actual closing time. Setting the valve to close in 50 seconds keeps the water-hammer pressure below the running pressure. Further, increasing the time of closing reduces the water-hammer pressure until with a closing time of 200 seconds the excess pressure caused by water-hammer is scarcely noticeable.

At this pumping station only one pump should be operated at a time if economical results are to be obtained. Two pumps can, however, be operated at once with a consequent decrease in the delivery per pump and a decrease in efficiency. The water-hammer pressure produced by closing the cone valve with two pumps in operation is practically the same as that produced by closing the valve with one pump in operation, the time of closing being the same. The reason for this is that while the actual closing time is the same, the effective closing time, as indicated by the curves, is about twice as long with two pumps in operation.

This method of reducing water-hammer pressures does not protect the discharge line from water-hammer pressures due to power failure. Such protection can be afforded only by a properly timed relief valve operated by a separate source of power or by the use of an air chamber, both of which methods have been previously mentioned. In the case of the Chazy Lake pumping station, neither of these methods seemed practical because of the difficulty of securing a separate source of hydraulic or other power; and, the very large size of the air chamber required to produce even a small reduction in the excess pressure. At this station the water-hammer pressures do not rupture the pipe but do strain the lead joints, and the high pressures can be repeated several times before leaks occur. For these reasons, it was decided to protect the pipe line against the high pressures produced by the daily starting and stopping of the pumps, and to risk occasional high pressures due to power failures which may occur at very infrequent intervals.

Beautification Has Been One of the Keynotes in Designing the Tallman's Island Plant

N. Y. WORLD'S FAIR PLANT GOES INTO OPERATION

Mayor La Guardia Dedicates New York's Newest Treatment Works and Starts Its Gas Engines

On April 22nd, one week before the opening of the New York World's Fair, the new Tallman's Island Treatment Works of New York City were officially started into operation by Mayor F. H. LaGuardia, seen midway of the dedicatory address, in the second picture of the accompanying strip.

The first picture shows the fitting location of the speakers' platform in front of the decorative fish pool—somewhat of a novelty for sewage treatment plants. The Tallman's Island Plant is here dubbed "the World's Fair Plant," because it was rushed to completion somewhat ahead of schedule set by the New York Department of Public Works in order that it might be in operation before the opening of the New York World's Fair, which is within the area served by the plant.

Because of its location, in one of the parkway areas under development on Long Island, considerable attention was given to beautification.

Of the unusual engineering features, possibly the most impressive is the fact that essentially all power required will be produced by eight gas engines developing in all 3,500 horsepower for driving pumps and air blowers. To supplement the gas supply from the sludge digesters, city gas is automatically taken from the mains of the gas utility whenever pressure on the sewage gas lines for any reason falls below a set pressure. The fourth picture in the strip above reveals a portion of the crowd surrounding the Mayor in the impressive power station, where he started the gigantic gas engines on their way to treating sewage of "International Complexion" — namely, that from peoples of many Nations who visit or inhabit the grounds of the New York World's Fair.

In closing his dedicatory speech, to the following effect Mayor La Guardia remarked, "Your Mayor is proud that another job of cleaning up New York's water-ways has been completed; and, now, *on to the next!*"

A STUDY IN MAIN STERILIZATION*

The Short-Comings of Yarn and the Development of a Mechanically Improved and Hygienic Method of Jointing

By CECIL K. CALVERT
Chemical Engineer, Indianapolis Water Co.
INDIANAPOLIS, IND.

The Author

FOR about ten years, it has been the practice of the Indianapolis Water Company to see that the pipe going into new lines is free from visible dirt and, thereafter, to place a small amount of calcium hypochlorite in each length as laid. Completed, the line was filled slowly, allowed to stand for a half hour and flushed thoroughly.

When the paper by Kingsbury & Adams (J.N.E.W.W.A., March 1937) on bacteria in hemp, appeared, our former practice was examined critically.

A careful use of the hypochlorite method of main treatment resulted in obtaining good samples from a new line just after flushing but on days thereafter the counts rose and coliform organisms were present in small portions of the water.

In published accounts of the treatment of new mains, various plans are followed involving the use of hypochlorite in the mains and in hemp, or the addition of chlorine as gas or hypochlorite after the line is finished. All authors and several operators, verbally or in correspondence state that good samples are obtained for a period after the chlorine bearing water is flushed out. Our own experience substantiates this statement; but, if the new main is sampled again in a few days the water is not good. It is easy to treat a main so that it will deliver good water immediately thereafter, but it is a hard matter to treat it so that the water will remain good as the days go by, especially in summer.

*A portion of a paper presented before the Indiana Section of A.W.W.A., with addenda on a new scheme of packing joints. The first part of this paper is reproduced on authorization by the Secretary of A.W.W.A.

The Kingsbury & Adams report caused us to concentrate on the joint packing material. Their findings were checked and substantiated in general. Jute was found to be worse than hemp and even good quality cotton yarn was found capable of feeding the natural bacteria in water, causing enormous aftergrowth in tap water.

Hemp may be sterilized by wet or dry heat but such treatment does not prevent subsequent growth of bacteria if the material becomes seeded. Treatment of hemp with effective concentrations of chlorine destroys the fibre and bacterial growth occurs when the chlorine is gone.

An organic mercurial sold under the trade name of "Klerol" (Reilly Tar & Chemical Co. of Indianapolis) seems to leave enough of the active substance fixed in the hemp to prevent aftergrowth for a considerable period. Laboratory tests gave better results than were obtained in the field, although good results are the rule on new sterilized mains in cold weather.

Method of Testing Packings

Two methods of testing hemp have been used.

Flow Through Method

A weighed length of hemp is coiled in a quart bottle which is supplied with tap water at a rate which will give a complete change of water in the bottle in two hours.

3 Day Cycle Method

A weighed portion of hemp is placed in a sterile quart glass stoppered bottle and 900 ml. of tap water added. The braided hemp is torn apart to expose single fibres. The bottle is stored at 20° C. for 3 days, portions removed for bacteriological examination, the water drained off and fresh tap water added. This is repeated for any desired length of time.

The 3 day cycle method gives more extreme results and is probably most satisfactory.

In the current series being examined in this manner, none have developed coliform organisms. The bacterial counts have increased in the treated hemp samples in this order, mercuric chloride alone and in physiological salt solution, copper sulfate and sodium carbonate, cupric ammonium and Klerol, about equal. Rubber such as is employed in an improved method of jointing, later to be described, is still good after 90 days.

Indications

Results indicate that "Klerol" and cupric ammonium treated hemp will hold bacterial counts down for more than 60 days at 20° C. and that rubber will not affect counts for at least 90 days with the normal winter tap water bacteria.

A 6-in. cast iron pipe 6 ft. long was swabbed with Klerol and plugged, using Klerol treated hemp. Tap water was passed through it at a rate to provide about 3 days' retention. The temperature was 14° C. The counts remained low for 30 days.

The pipe was then moved to a warmer location in which the temperature was 22° C. At the same time, two more pipes were added to the test. One pipe was swabbed with Klerol and the other was put in test just as it came from the storage yard. The latter contained visible dirt. Both pipes were plugged, using heat sterilized lead wool in the joints instead of hemp.

The three pipes have been in test for 60 days. The old pipe, which was moved from a cold to a warm location produced high counts at once, which are still increasing. They are now higher than those from the dirty pipe jointed without hemp. At first, the dirty pipe produced higher counts than the one swabbed with Klerol. The Klerol swabbed pipe produced

counts which were usually above 1000 per ml.

It appears that the normal tap water bacteria multiply at the temperature provided though they do not do so in bottles at 20° C. The Klerol treated hemp seems to have lost the effect of the sterilizing agent and to be in a condition to supply food for bacteria.

Coliform organisms have been recovered only twice from any pipe, both times from the one swabbed with Klerol and jointed without hemp.

During the summer of 1938 nearly 800 samples of water from 37 new mains (all but one treated in some manner) were examined for total counts and the presence of coliform organisms in five ten ml. amounts. In addition, considerable chemical work was done in the laboratory and field. It was found that fire hydrants generally yield bad samples. In all of this work a special sterile tap was used protected against air contamination.

In the summer, few of the lines laid were perfect though many of them were nearly so. The Klerol treatment of hemp and pipes does not guarantee that the line will deliver as good water as it receives. However, any degree of concentration of Klerol in a solution used to treat hemp will improve the condition of the water delivered by the lines and the character of the water will improve with increased concentrations of Klerol.

Chlorination Futile

The chlorination of new mains, laid with hemp, is futile in so far as permanent results are concerned. Chlorine appears not to penetrate the hemp and even if it does, the bacteria will grow when the chlorine is gone.

The following is an example. A 12-inch line, 640 feet long was laid with no treatment of the pipe or hemp but care was used to keep out dirt. After laying, it was flushed thoroughly. Chlorine was applied. At the end of 43 hours it was removed and at this time more than 90 ppm. of residual was found.

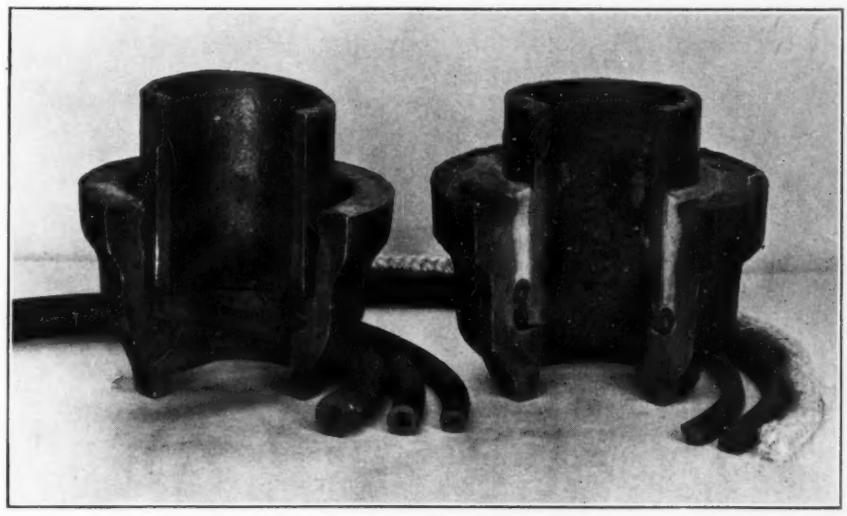
Twenty minutes after the last trace of chlorine was found, 15 ten ml. portions were planted, none of which contained gas formers. The counts were 5 or under per ml. and the results were temporarily satisfactory. Twenty-one hours later, however, the counts averaged nearly 500 per ml. and of 20 one ml. portions, 18 actually contained coliform organisms.

The line was sampled frequently for a period of 56 days. It showed some improvement toward the end but even then about 5% of the 1 ml. portions contained coliforms and the counts were higher than normal.

After two years of main sterilization work, which has been quite extensive, it is felt that the condition of new mains has been considerably improved, but that present methods are not sufficiently satisfactory; and, if there can be found a better method of main sterilization or scheme of eliminating the bacteria breeding jointing materials, now employed, such should be welcomed by operating men as well as health authorities.

A New Method of Joint Packing Possibly the Solution

A new method and material, to replace the use of hemp, jute or yarn in joint making, has been developed and recently introduced by Mr. Hayes R. Kuhns, for many years the representative of the Leadite Company in this territory. The inventor personally conceived the scheme—after having heard of present day troubles with joint packings.



The New "FLEX-SANIPAC" Joints

Note over-lap of tubing ends (double row) in the poured joint; the oval air space within the tubes, and tight seal produced by the snug fit of the compressed rubber. Joint compound in pouring condition is not hot enough to burn the rubber and "bugs" refuse to grow on it.

[Mr. Kuhns, we understand, will exhibit his new jointing method at his firm's booth during the forthcoming Convention of A.W.W.A. in Atlantic City, June 11-15. —Ed.]

The material, seen in the accompanying picture, is rubber in the form of heavy-walled tubing or solid wedge-shaped strips. Both materials come in coils, from which strips of proper length are cut as needed. The cost per joint of pipe packed with the rubber tubing or strip is reported to be substantially the same as for hemp of good quality.

Mr. Kuhns has named his method the "Flex-Sanipac" method. Experimental application of the new "rubber yarn" has been under way in about a dozen cities in addition to Indianapolis. The workmen seem enthusiastic about it because it is easier to handle the new packing than it is to handle and caulk hemp or jute. The joints are made up faster, and the caulking is extremely simple, producing an even space between bell and spigot all around the pipe. The tubing has advantages of elasticity, ease of placement, and compensation of irregularities, which makes it somewhat preferable to the solid strips. In the picture of the cut-away sections it can be seen how the tubing conforms in place, and the double row of tubing on the left of the view on the right, indicates the lapping of the two ends. The tubing, with its oval hole filled with air, forms a cushion which has potential advantages in producing drop-tight joints before compound-healing takes effect and likewise in shock cushioning.

The effect of the rubber on the quality of the water cannot be told as yet, with certainty. However, with the limited area of rubber exposed, it is hardly likely that taste troubles will be experienced any more than is experienced with double rubber gasketed couplings now considerably employed on water mains,

and even on house service lines to some extent.

Concerning Bacterial Growths

Samples of the new "rubber yarn" have been under test for about 90 days now, using both the 3 day cycle and the "flow-through" methods of test. In no case has the rubber caused an increase in total bacteria, nor have any coliform organisms appeared in the water in contact with the strips or tubing.

In order to get good water immediately from a main laid with the new "FLEX-SANIPAC" joints it appears that the pipes should be swabbed with Klerol, or equivalent, just before laying, or else heavily chlorinated just after laying. A line so treated will, according to our experience and results of studies made at Indianapolis, prove bacterially satisfactory.

The Inventor.
Hayes R. Kuhns of Killbuck, Ohio., and his interesting "rubber yarn" joints.

Mains have been laid for at least a century, with only recent attention being given to main sterilization before placing it in service. Apparently the bacteria which multiply in hemp do not cause illness of consumers. However, such bacteria do not come labeled and they can not be distinguished from significant coliform organisms.

It seems unjustified to lay a new main under any but the best conditions possible to attain, and the improved jointing method and materials may add materially to such a desired attainment.

Whatever else we may do at the water plant, let's keep at the new ideas.

What Atlantic City Has to Offer

Although the upper foreground view can not be guaranteed during the rapidly approaching A.W.W.A. Convention in Atlantic City June 11-15th, in the rear appears this resort's far famed Million Dollar Steel Pier A.W.W.A. has engaged for the Wednesday afternoon "Frolic." Here, on that day all of the many attractions will be "wide open" to A.W.W.A. conventioneers, exclusively. There will be plenty of slot-machines and big-time games of chance. The play will be made with A.W.W.A. money, coined for the occasion, with which every member will be staked equally. Those who come out with the most "blood" when the final gong rings will take home prizes commemorative of the 1939 Convention.

(By the way, Miss Chicago seems to have been three years ahead of the 1939 styles in ladies' headgear. None the less, we prefer the roguish style of Robin Hood head piece, as worn by Miss Virginia,—Ed.)

Now, as to the lower picture:

These 48 in. twin mains (the pride and joy of Super. Van Gilder), crossing the salt marshes behind Atlantic City on piers above high water elevation, will be very much in evidence.

The question which will arise in the minds of many curious water works men is why the bells point toward town on one line and toward the pumping station on the other.

Come to the Atlantic City Convention. See many Miss Americas on the board-walk, if not on C. I. Pipes. Oh, Yes and ask Super. Van Gilder to tell his story of "Why the elevated twin lines," and "Why the bells look fore and aft." The history of Atlantic City's water supply mains constitutes an interesting "Adventure in Pipe Lines and Materials."

ATLANTIC CITY SELECTS CAST IRON PIPE
FOR ITS WATER SUPPLY SYSTEM
The NATIONAL BEAUTIES of 1936
STAND ON ITS APPROVAL
DANCING

Top view of Permutit Spaulding Precipitator installed in a midwestern municipality. (Name on request.) This new Permutit development is revolutionary for the quality of water it produces. And it takes less space, less time, and less chemicals than conventional cold lime treatment.

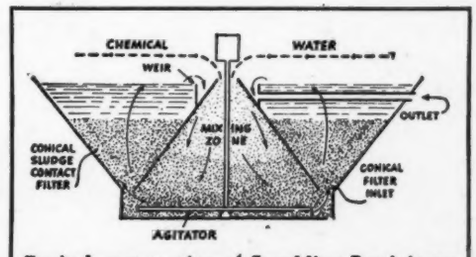
That's the News about PERMUTIT'S SPAULDING PRECIPITATOR!

Here's a cold lime treatment that beats anything you've seen for efficiency, both in design and in operation!

Here's how the Spaulding Precipitator works: Sludge is not permitted to settle. Instead, it's kept in constant suspension by means of an agitator. (See diagram.)

A good portion of old sludge is always retained in the Precipitator. This mixes with the newly forming sludge, speeds precipitation, acts as a contact filter at the same time.

The conical shape of the chamber lowers velocity of the water as it rises. Sludge drops out, leaves effluent clear, sparkling, so stable it often needs no recarbonation!



Typical cross-section of Spaulding Precipitator

Write for booklet. Also booklets on Permutit Zeolite Water Softeners, Iron Removal Plants, and other automatic accessory equipment. The Permutit Company, Dept. G1, 330 West 42nd Street, N. Y.

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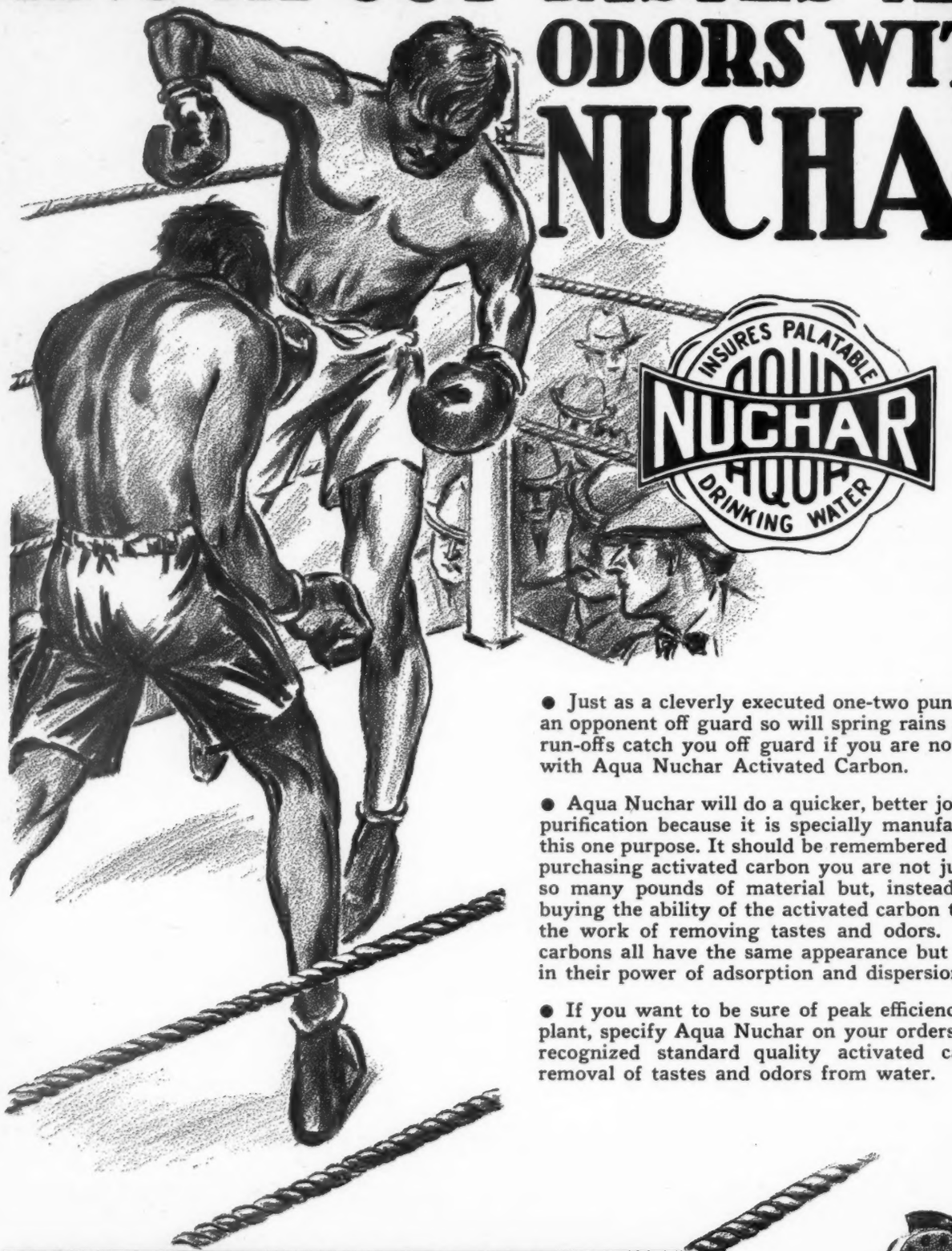
KNOCK OUT TASTES AND ODORS WITH NUCHAR



● Just as a cleverly executed one-two punch catches an opponent off guard so will spring rains and heavy run-offs catch you off guard if you are not prepared with Aqua Nuchar Activated Carbon.

● Aqua Nuchar will do a quicker, better job of water purification because it is specially manufactured for this one purpose. It should be remembered that when purchasing activated carbon you are not just buying so many pounds of material but, instead, you are buying the ability of the activated carbon to perform the work of removing tastes and odors. Activated carbons all have the same appearance but they vary in their power of adsorption and dispersion.

● If you want to be sure of peak efficiency in your plant, specify Aqua Nuchar on your orders; it is the recognized standard quality activated carbon for removal of tastes and odors from water.

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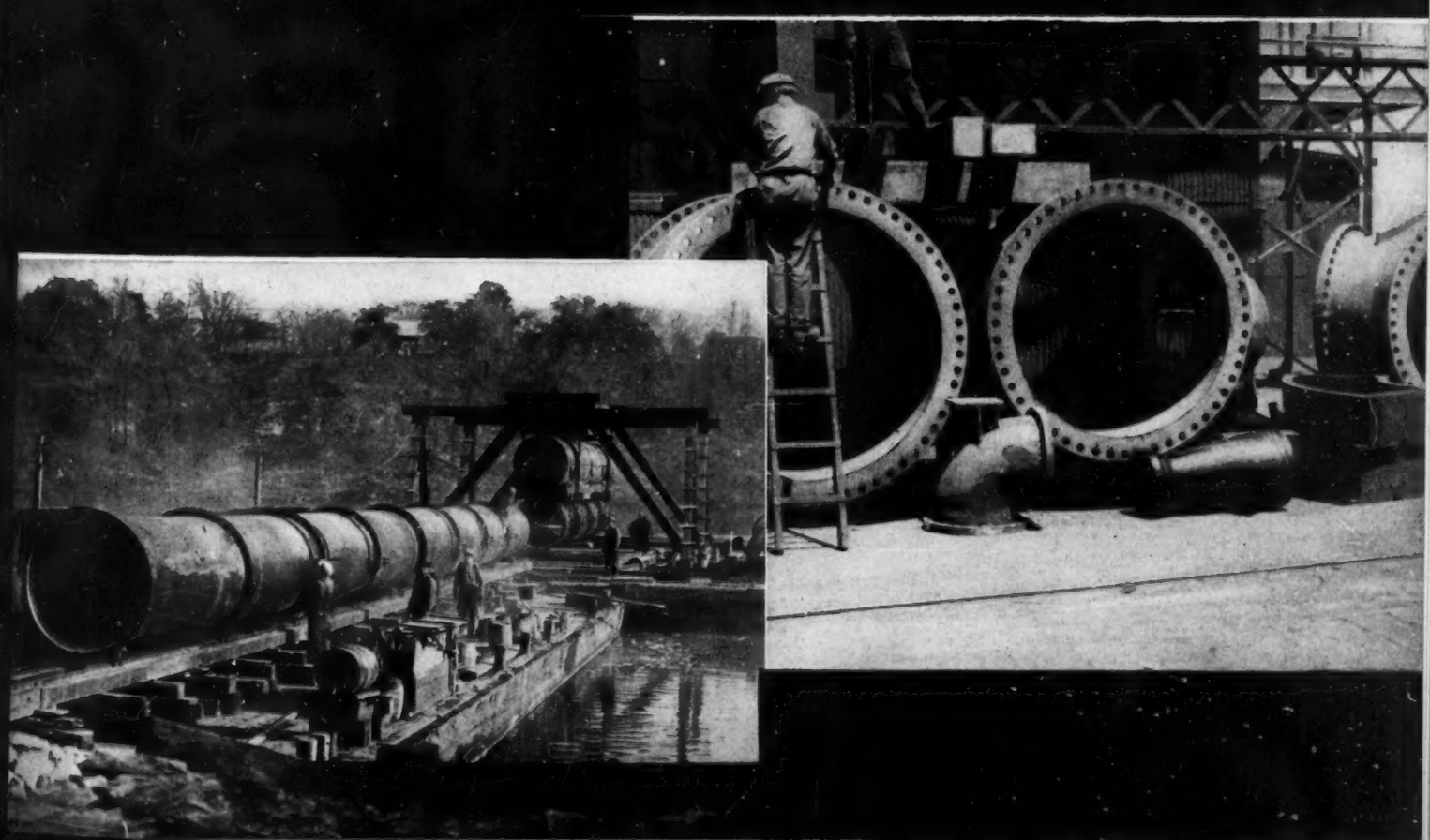

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COPPER SULPHATE IN THE WATER PURIFICATION PLANT

Some New Aspects of Its Usefulness and Methods of Application

By PAUL WEIR*
Supt. of Filtration
ATLANTA, GEORGIA

The Author

COPPER Sulphate has been used successfully to prevent or retard growths of algae and other microscopic organisms in water purification systems, now, for almost forty years.

Knowledge of its application and usefulness compares favorably to that of aluminum sulphate or chlorine in the average water treatment plant. In fact, the utilitarian value of copper sulphate in the water purification plant has now come of age and it should be considered in the same light as other chemicals in the water treatment field. It should be applied by calibrated equipment of a permanent nature and not promiscuously fed through a dilapidated contraption. Proper equipment means effective and economical control. This procedure not only provides a more scientific and equitable basis of application; but also tends to reduce loadings on subsequent chemical treatment by removing substances which frequently interfere with clarification, filtration and chlorination.

During the past ten years, marked progress has been made in developing copper sulphate feeding equipment. There are at least a dozen reliable machines on the market. And, there are twice this number of home-made ones, plans for which can be had for the asking, but it is the writer's opinion that copper sulphate equipment should be of a dependable and permanent nature, capable of operating any day or season of the year.

The manufacturers of copper sulphate have consistently improved the quality of their product and the method of its distribution, until it is now practically universally obtainable. Copper sulphate is essentially chemically pure, 25% of its weight being pure copper. It can be secured in a variety of crystal sizes from large lumps, to fine powder. It is conveniently packaged in wooden barrels and 100 pound bags.

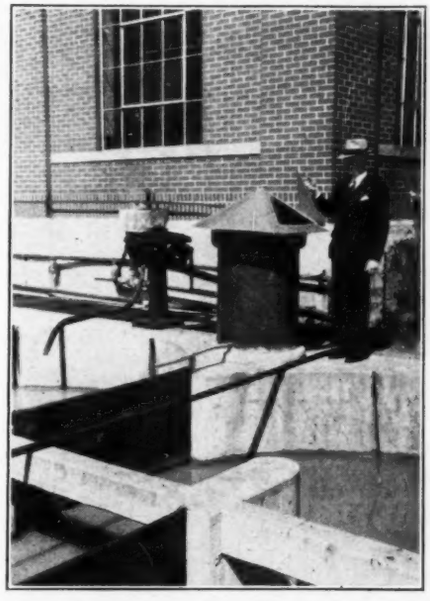
Copper sulphate is usually applied at two principal points in the purification process:

I. Open storage reservoirs.
II. In conjunction with other purification chemicals.

Methods of Application

Alone

The following four methods are most generally used in treating open storage reservoirs, depending upon their size, intensity of organism, propagation, and available equip-equipment.



One of the Atlanta Copper Sulphate Feeders
(Modified Shelton Design) Constructed by Atlanta Water Department (See detail sketch)

(a) Porous bag suspension.
(b) Perforated dispersion box or basket.
(c) Solution spray—(surface atomization).
(d) Pulverized crystal blower—(surface dusting).

One of the simplest methods of copper sulphate application consists in the placing of about 25 pounds of the crystals in burlap bags, or porous baskets, and attaching them to a boat, either astern or at the sides so that they will drag in the water to be treated. Additional refills may be used as needed. It has been frequently suggested that the boat should follow a definite course, one series of parallel paths from 20 to 50 feet apart, and if the reservoir is deep, a second course should be made at right angles to the first in grid-iron formation.

Another method has been developed at Atlanta, whereby the shore line and areas too shallow for boat travel may be treated in an effective and economical manner. An inflated automobile inner tube is laced with rope or heavy twine, in a spider web or net effect. This floating basket supports a 25 pound bag of copper sulphate. A 25 to 50 foot sash cord, attached to the inner tube, permits a person to pull this device easily from the shore line. Atlanta has two raw water impounding reservoirs with a total surface area of 60 acres. Each reservoir has approximately 6,000 feet of shore line which requires 150 pounds of copper sulphate thus applied each month.

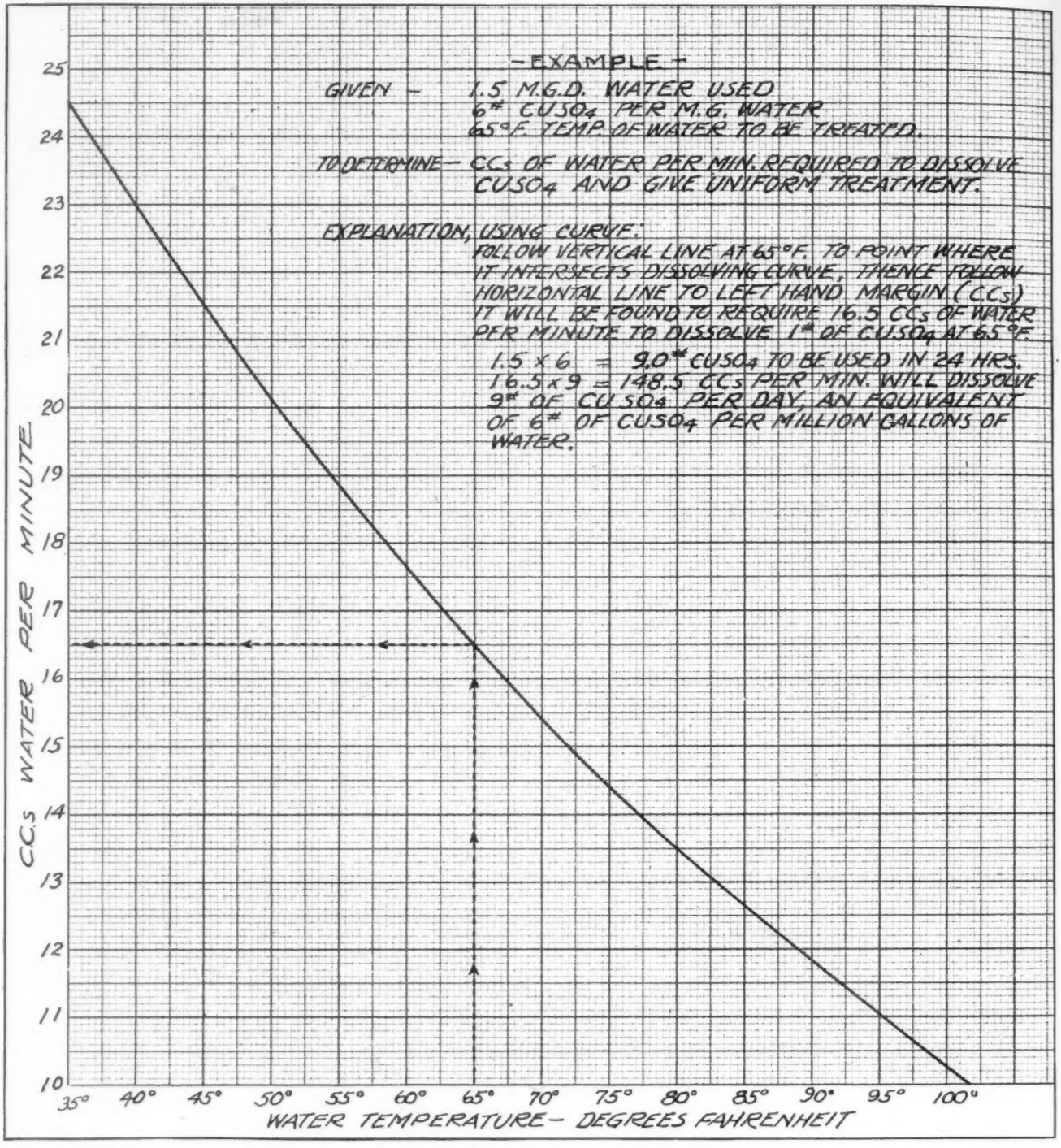
There are certain circumstances, however, that are not conducive to this simple method of treatment. It may be more expedient and economical, on the whole, to use the dispersion box and the spray or dry crystal blower methods of distribution.

With Other Chemicals

It has been frequently found necessary to apply copper sulphate continuously, at the inlet of the mixing

*The author of this article is Chairman of the Southwestern Section of A.W.W.A.

COPPER SULPHATE FEED-RATE GRAPH


-EXAMPLE-
GIVEN - 1.5 M.G.D. WATER USED
6# CUSO4 PER M.G. WATER
65°F. TEMP. OF WATER TO BE TREATED.
TO DETERMINE - CCs OF WATER PER MIN. REQUIRED TO DISSOLVE CUSO4 AND GIVE UNIFORM TREATMENT.
EXPLANATION, USING CURVE:
FOLLOW VERTICAL LINE AT 65°F. TO POINT WHERE IT INTERSECTS DISSOLVING CURVE, THENCE FOLLOW HORIZONTAL LINE TO LEFT HAND MARGIN (CCs) IT WILL BE FOUND TO REQUIRE 16.5 CCs OF WATER PER MINUTE TO DISSOLVE 1# OF CUSO4 AT 65°F.
1.5 x 6 = 9.0# CUSO4 TO BE USED IN 24 HRS.
16.5 x 9 = 148.5 CCs PER MIN. WILL DISSOLVE 9# OF CUSO4 PER DAY. AN EQUIVALENT OF 6# OF CUSO4 PER MILLION GALLONS OF WATER.
CCs WATER PER MINUTE
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
35° 40° 45° 50° 55° 60° 65° 70° 75° 80° 85° 90° 95° 100°
WATER TEMPERATURE - DEGREES FAHRENHEIT

From This Graph is Determined the Rate of Water Feed Required to Dissolve and Feed the Desired Dosage of Copper
Courtesy—Tennessee Copper Co., Copper Hill, Tenn.

Use of the graph in arriving at the correct water rate setting per pound of copper sulphate required per hour is explained on the graph. The solution discharged is saturated, varying in concentration with the temperature of feed water, consequently the need for water temperature readings and use of this helpful graph

chamber, or at other convenient points, during times when microorganisms are most abundant and are not entirely reduced by reservoir treatment alone. This may be accomplished by making a concentrated solution in a paraffine-lined wooden barrel, or other acid resisting container. An orifice or stopcock drains the solution from the container into the water to be treated, necessitating recharging at frequent intervals. This type of equipment is usually a makeshift and is not conducive to uniform and economical feeding.

We at Atlanta have endeavored to make our copper feeding equipment permanent — (see illustrations). These feeders are of the solution type (modified Shelton design), and are mounted out-of-doors at the influent and effluent ends of the mixing chamber. A standard 3 foot length of 24 inch diameter terra cotta pipe is set in 4 inches of concrete grout, with the bell at the top.

The lower 18 inches of this pipe is filled with sand and sealed with about 3 inches of concrete. Into the top 18 inches is fitted a circular lead container which rests upon the concrete slab. A heavy walled lead pipe of 1 in. diameter leads from the bottom of the circular lead container down and through the side of the terra cotta pipe and to the point of application. A small, circular, perforated lead baffle fits over the inlet to the feed line to prevent stoppage. Dry crystals (random size) are placed in the circular lead dissolving pot. Water from a ⅜-in. copper line flows through a pressure reducing valve, thence through a small orifice where it drips onto the copper crystals, forming a uniform saturated solution of copper sulphate. This flows out at the bottom of the pot. The quantity of copper sulphate is readily controlled by a calibrated needle valve, which admits the water through the orifice into the bed of copper crystals. The water flow is set in accordance with the temperature-solubility curve, here reproduced, so as to secure the desired rate of copper application.

Simplicity of Equipment and Operation

An attractive metal mushroom-type cover protects the equipment from the elements (see photograph). This apparatus is inexpensive to build, easy to operate, and is subject to accurate calibration to give the required dose. Its neat design makes it an asset to any plant. It will operate without adjustment for days, still maintaining the original setting and feed rate. One decided advantage, over many other types of home-made equipment, is that the control involves the feeding of nothing more difficult than pure water through the small orifice, rather than a corrosive or encrusting solution, as is usually the case with solution feed equipment. Small particles of foreign matter or undissolved crystals soon obstruct most any type of restricted orifice when employed in feeding copper sulphate solutions.

[Familiarly like the Shelton-Atlanta solution feeder is the "Economy Chemical Feeder" described in the Equipment News Section of this issue.—Ed.]

Dissolving Water at Constant Temperature

It becomes apparent, from a study of the chart employed in arriving at the flow rate for the dissolving water stream in dosage manipulation, that if the supply of dissolving water could be produced at a constant temperature, or at a temperature which fluctuates but slightly, a worth while advantage accrues.

To attain such a desideratum, or an approach thereto, consideration of a scheme for producing a supply of water at ground water temperature, as developed in the Atlanta Water Department, is suggested. This scheme is an invention of Mr. William Rapp, Atlanta's Superintendent of Construction and Distribution, which was first described and illustrated in detail in "Water Works and Sewerage". The descriptive article and drawing was reprinted on page 358 of the Data Section of the very useful April, 1938, issue. It is hoped that it may be found also in the same issue for which this article is being prepared, since it is the writer's understanding that such will be the Special Reference & Data Issue for 1939.

In brief the scheme consists of employing an existing well, or putting a new 4 inch well down into ground water to such depth that a 5 foot long coil, made up of pure copper tubing, may be submerged in the ground water for the most part if not completely so. The inlet (upper end) of the coil connects to a drop pipe from the city supply main. The outlet (lower end) discharges through a ⅜ in. riser of copper tube, running up alongside of or through the center of the coil. The city water supply will be cooled or warmed, as the case may be, to the rather constant temperature of the ground water which is constantly moving across non-pumped wells, or upwards through pumped wells. By this method, in Atlanta, water has been cooled and kept flowing under pressure from the mains at 66 deg. F., although the city water entering Mr. Rapp's "ground cooler" has been as high as 87 deg. F. and down to 83 deg. F. during the 30 day summer period.

In connection with the production and displacement of a saturated solution of a chemical in dosage control, the matter of *what* temperature is not the important consideration, but rather the production of a fairly *constant* temperature feed water, and knowledge of the concentration of saturated solution at such temperature. Naturally, some thought must at the same time be given to insulation of the dissolving pot in order that the chosen water temperature may be maintained fairly constant while passing through the saturation-pot.

We realize that there are other controllable methods of producing water at thermostatically controlled temperatures, with constancy, but we rather enjoy the idea of letting Nature contribute its bit through use of the economical and fool-proof equipment and scheme of the eminently practical Mr. Rapp.

Effect of Copper Sulphate on Organisms

The effect of copper sulphate differs with different organisms. This is due, not only, to their relative susceptibility to copper salts but also to the rapid growth of certain species after the death and decomposition of the more susceptible organisms.

The nature of algae, which develop in water, depends upon the clearness of the water, concentrations of oxygen, free carbon dioxide and bicarbonates, pH value, temperature, season of year and possibly the species of fish inhabiting it.

Copper sulphate owes its high degree of toxicity to the lower plants due to the copper ion. The toxicity of the copper ion is highest for the simplest algae, the cyanophyceae, and lower for the more highly developed forms of the chlorophyceae. Protozoa are generally less susceptible. The diatoms are readily killed. Higher fungii (Schizomycetes, etc.) tend to be more resistant, although here too there is a wide variation. The higher plants, such as water weeds, are in general not controlled by copper sulphate treatment as the copper ion is only slighty toxic toward them. Bacteria are also essentially unaffected by the concentrations which can be attained practically.

Microscopic examinations and threshold odor tests are important in attaining efficient application and control. There is not one fixed dosage of copper sulphate suitable for any one condition; but, generally speaking, an application of 2 to 10 pounds per million gallons of water will be found effective in the elimination of the most objectionable microscopic growths. And, continuous application of small doses usually gives good results in bringing about practical elimination of most of the more common and troublesome types. A twelve month program of application, on larger reservoirs, and early season control in mixing chamber, etc., makes possible the use of small applications and effects a maximum of organism reduction without taste and odor formation.

Copper sulphate should be used to *prevent* microscopic growths in a water purification system, rather than to kill the organisms after they have grown to large numbers. A small quantity of copper sulphate applied continuously during the growing season, or certainly at frequent intervals, will keep growths at a minimum and will also prove overall a more economical procedure.

When it is convenient to lower the water line in a water treatment plant or dewater it entirely, algae adhering to the walls may be eliminated by spraying or washing the exposed area with a 5% solution of copper sulphate.

Some Experiences

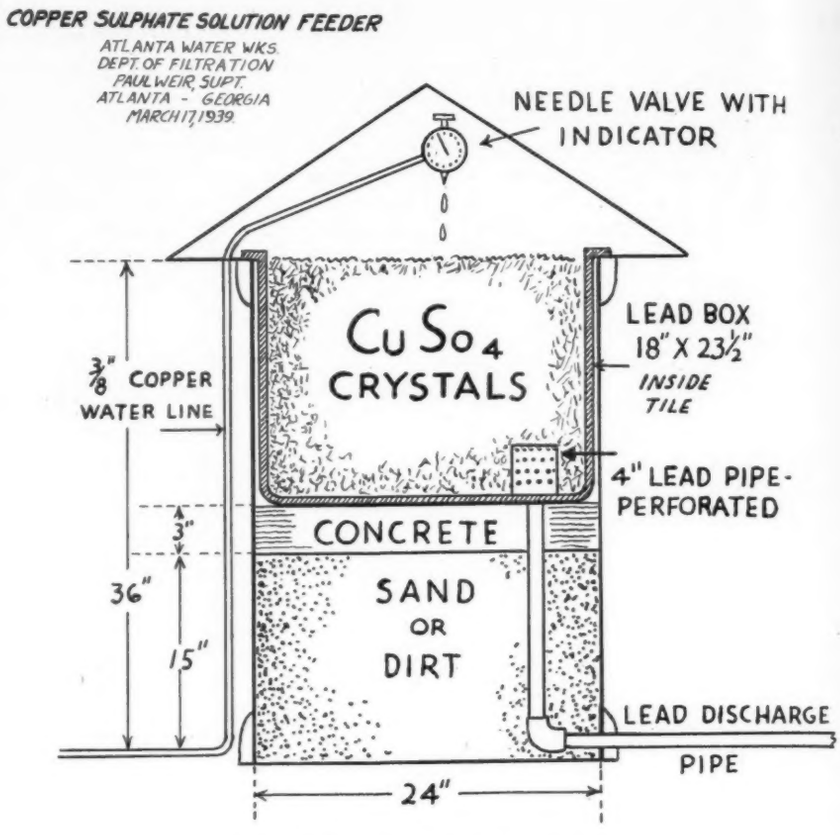
At El Paso (1), Woods controls algae formation in his purification process by spraying the vertical walls of the dewatered basins with a copper sulphate solution. The spray solution is prepared by dissolving 50 pounds of copper sulphate crystals in a tub of water.

At Atlantic City (2), Van Gilder reports applications of a strong solution of $CuSO_4$ to the concrete walls of his basins after cleaning and prior to refilling.

At Council Bluff (3), Bailey used 5 pounds of $CuSO_4$ crystals per 100 lineal feet on sloping walls. Solution of the crystal thus formed rolls down the walls, killing the algae.

At Nashville (4), Lawrence was confronted with objectionable growths in a filtered water reservoir, holding 50,000,000 gallons. Growths were interfering with prechlorination residuals, requiring a post treatment of 14 pounds of chlorine with 5 pounds of ammonia per million gallons. He found 8 pounds of copper sulphate per million gallons so effective in controlling algae formation that secondary chlorine application at reservoirs could be abandoned, with a decided improvement in the plant effluent chloramine residual. It is now a regular practice to apply copper sulphate to this reservoir every two weeks in the summer and less frequently in the winter. Savings as high as $4.50 per day have been realized during the summer.

At Greenville, S. C. (5), Hawkins operates a water system from a mountain lake having 12 miles shore line, located 35 miles from the city. Soda ash and chlorine are applied to the water by means of automatic pH and chlorine control equipment to insure uniform quality of water when delivered to the city and several textile processing mills. In the spring of 1935, it was practically impossible to deliver a water of uniform pH value. The readings in the city were several points lower than those at the lake. It was found that dead organisms decomposed between the point of chlorine application at the lake and the city outlets. This decomposition probably liberated carbon dioxide, thereby upsetting the pH value. Routine copper sulphate treatment in the lake was then started. It killed the algae and permitted the dead organisms to settle before chlorination at the lake outlet. The automatic pH control system was then restored to normal. At Greenville 4 to 6 pounds of $CuSO_4$ per million gallons is now used regularly to control algae.



The Atlanta Copper Feeder in Detail
(Note simplicity of construction and dosage control by needle-valve setting for water feed only)

At Lyman, S. C. (6), Bright had difficulty in ridding a 5,000,000 gallon clear water reservoir of tadpoles. A substantial chlorine residual did not seem to affect them. However, 5 pounds of copper sulphate per million gallons was effective in their elimination. This treatment is carried out at regular intervals during the summer months and occasionally through the winter.

Filter Bed Clogging

A number of water plant operators have experienced a partial if not an almost complete clogging of filter beds by micro-organisms. Greatest relief has been had when copper sulphate treatment was begun and continuously applied during the propagation season. Diatoma and synedra are usually the chief offenders and may be killed, or reduced, by using approximately 2 to 6 pounds of $CuSO_4$ per million gallons of water.

At Spartanburg (7), Marquis describes a situation where a new plant was put into service, after the supply reservoir had been idle a long time, permitting a luxuriant growth of algae. Rapid sand filters became so densely matted with algae that filter runs were reduced to 1½ hours between washings. The wash water consumption reached 25% of the total pumpage and the city was on the verge of a water shortage. Copper sulphate was immediately applied to an area 1,000 feet in front of the raw-water intake by dragging copper sulphate crystals in a burlap bag fastened behind a boat. Approximately 13 pounds of $CuSO_4$ were used for each million gallons of water. This treatment was continued daily until relief was apparent at the filter plant. After the initial emergency was over, copper sulphate was regularly applied by solu-

tion feed at the inlet of the mixing chamber. Dosages ranged from 2 to 13 pounds per million gallons. This same procedure has been followed yearly since, without similar reoccurrence.

A few years ago, Atlanta experienced the formation of troublesome sheets of microorganisms, in the impounding reservoirs, which reduced filter runs from 120 hours to 20 hours between washings. Taste and odor complaints ensued. This was rectified by monthly applications of $CuSO_4$, at the edge of the reservoir and also continuous application at the inlet of the mixing chamber, when the raw water turbidity drops below 25 p.p.m. At such times 2 to 7 pounds of $CuSO_4$ per million gallons of water are used to combat these growths, with satisfactory results. The continuous application of 4 pounds of copper sulphate per million at Atlanta, during periods of algae propagation, has materially reduced tastes and odors, chlorine consuming substances, and coagulant used. This results in a more palatable drinking water, at a reasonable cost, and filter runs at Atlanta are almost directly proportional to the concentration of micro-organisms in the *applied* water.

The Question of Copper on Health

It is believed that the judicious use of copper sulphate to prevent and kill algae in water purification systems is not harmful to health and is sanctioned by practically every State Department of Health in the U. S. A. (8).

Years ago, the United States Public Health Service set an arbitrary limit of 0.2 p.p.m. of copper (Cu) in drinking water at the tap. This would permit the direct application of approximately 6.7 pounds of $CuSO_4$ to each million gallons of tap water (9).

Reliable authorities (10) have more recently proven that doses of $CuSO_4$, as high as 100 pounds per million gallons, could be used with alum coagulation, if the pH of the water is above 6.3, without danger of copper passing the filters.

Negus (11) states that it is necessary for about 30 p.p.m. of copper ions (120 p.p.m. of copper sulphate) to be present in water to stain white plumbing fixtures. He further states that research and experience have proven that a copper limit of 0.2 p.p.m. (about one-half the amount present in cow's milk) is much lower than necessary. Conservatively, five times this amount (1.0 p.p.m.), would still be considered safe.

Uses Other Than as an Algaecide

Copper sulphate is said to increase the toxicity of ammonia-chlorine sterilization under certain conditions.

When filtration is not a regular step in the purification process, copper sulphate may be applied in the impounding reservoir in conjunction with alum or activated carbon.

Copper sulphate has been successfully used, with aluminum sulphate, to control algae growths on the vertical side walls of reservoirs and basins. Eight to 16 pounds per million gallons of copper sulphate proved satisfactory in this undertaking (12).

At Greenville, Tenn. (13), McAmis successfully kills roots in sewers with copper sulphate. About 5 to 10 pounds of copper sulphate crystals, applied in the manhole upstream from the stoppage, killed the feeder roots, which in turn, broke off and released the "root bush" which forms the obstruction.

Copper salts are highly effective coagulants and Damn and Bock (14) report that when milk waste was treated with two pounds of copper sulphate to between 225 and 275 cu. ft. of waste a good floc was produced. A clear effluent was obtained by passing the flocculated material through a magnetite filter. The precipitated sludge is said to have possibilities as a fertilizer.

At Indianapolis (15), Calvert on an experimental basis has successfully used a copper sulphate powder of low solubility to keep pipe jointing yarn from growing organisms. In sewage treatment copper sulphate has been used to check fermentation of sludges.

Conclusions

Fundamentally, all structures entering into the storage, purification, and distribution of water supplies should be maintained in a high degree of cleanliness, free from slimes, growths and deposits. Treatment with copper sulphate continuously, where possible, or intermittently where absolutely necessary due to local conditions, accomplishes this.

Experience in many plants shows that copper sulphate contributes to better operations not only through algae control but betterment of plant operation by its effect upon floc, filter condition, and appearance of finished water.

Copper sulphate remains the most over-all effective and economical algaecide. It is best used as a preventative treatment by checking algae propagation. Effective algae control results in a higher quality water at a reduced chemical cost.

Copper salts are not harmful to health when applied to the water in reasonable or practical quantities, and can be used in doses from 2 to 10 pounds per million gallons of water, or even more. This application will control almost any type of microscopic growths, *if used in time.*

High alkalinity or low temperature waters require higher copper sulphate dosages to control microscopic growths than do soft or high temperature waters.

During 40 years of usage copper sulphate has demonstrated its indispensability in water treatment and deserves regard as one of our most important water purification chemicals.

Also, in sewage and industrial waste treatment its usefulness has been demonstrated.

Like the famed "ounce of prevention," a pound of copper effectively timed and placed is worth more than "tons" of regrets and explanations.

[**In Appreciation**—I wish to express my sincere appreciation to W. Z. Smith, general manager of the Atlanta Water Works, for his suggestions and help in conducting the work with copper sulphate at Atlanta, to the purification plant employees, and to others who have generously contributed data employed in preparing this paper.]

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MAINTENANCE OF TANKS AND STANDPIPES*

By WILLIAM S. STAUB
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CHARLESTON, W. VA.

The Author

THE elevated tank or standpipe is one of the most costly single items amongst aboveground structures of a water system. Yet as a general rule they receive the least attention and very little is done in the way of yearly maintenance to keep the valuable units in first class condition. Tanks are generally located in inaccessible or out of the way places and the public is not afforded the opportunity to offer criticism of their appearance and, frequently, deteriorated condition. The condition of an isolated tank will generally provide a good barometer as to the condition of the remainder of any given water supply system. A well maintained tank represents to me that other structures and equipment comprising the system will be in good condition.

A tank is located in a distribution system to

1. Provide for peak demand.
2. Provide for uniform pumping head.

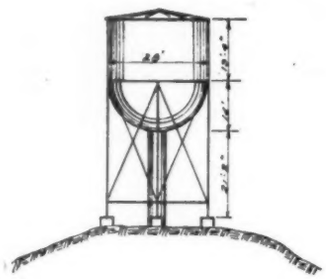
Peak demand may be subdivided into domestic, commercial, industrial and fire-demand. By providing some several hours of storage, we are able to operate with filtration plants, pumping equipment, etc. much smaller output capacities than otherwise. With adequate storage, properly placed in respect to the system design, conservative uniform output may be used which will make possible the performance and efficiency of pumping equipment at maximum economy and insured service expectancy.

Some Basic Considerations

Many maintenance worries may be eliminated by considering basic principles when plans are being drawn preliminary to tank erection. Proper foundations, anchorage, maintenance, accessories, painting and rigid inspection will prevent many abnormal maintenance worries.

Sufficient foundation should be provided that unequal settling and abnormal stresses in the tank may be eliminated. Heat, cold, wind, high and low water levels, all cause stresses in the tank that may tax the physical qualities of the material, without introducing those that may be prevented. The writer's company has built five standpipes at Charleston during the last two years. The largest of these was a riveted steel tank 100 feet in diameter, 52 feet high, with a capacity of 3,000,000 gallons.

CONSTRUCTED 1924
BY P.th. D.M. Steel Co.
CAPACITY 100 000 GALLONS



YEAR	EXTERIOR	INTERIOR	FOUNDATIONS	RISER
1930				
1931				
1932				
1933	Good	Good	Good	Good
1934	Good	Good	Good	Good
1935	Fair	Good	Good	Fair
1936	Fair	Good	Good	Fair
1937	Fair	Good	Good	Fair
1938	Painted	Good	Good	Painted
1939				
1940				
1941				
1942				
1943				
1944				
1945				
1946				
1947				
1948				
1949				
1950				

WEST VIRGINIA WATER SERVICE CO.
CHARLESTON
LOUDON HEIGHTS TANK

Specimen, Inspection Record and Sketch Sheet

Foundation and Bottom Important

All of these tanks have been constructed on foundations consisting

*This paper, presented before the West Virginia Conference on Water Purification, is being published with permission of the Conference.

of reinforced concrete rings. The foundations of these rings have been placed on rock and sufficiently anchored. The interior of the rings, upon which will rest the bottom plate of the tanks, have been built up of thoroughly compacted earth, capped with a 10 inch gravel mat and in turn capped with a 2 inch sand mat. The sand mat is always permitted to rise about 1 inch above the top level of the ring. This allows cushioned uniform settling when the weight of the full tank is superimposed. At the bottom of the gravel mat we have placed a grid system of 1 inch and 2 inch perforated galvanized pipe. Short nipples of this grid project through the concrete ring and are capped. After the tank has been constructed the voids in the sand and gravel are filled with oil through this grid system. In this manner it is possible to keep protective oil in contact with the bottom of the tank instead of water produced by sweating, rain or seepage, corrosively oxygen saturated.

The bottom plates of the tanks have been welded and we specify that an asbestos strip 6 inches wide be placed at each lap. Over this strip and the entire bottom of tank "No-Oxide" [A] Special or a similar substance is placed. The asbestos strip prevents the burning of the "No-Oxide" coating when the plates are being welded.

Sufficient anchorage is always used so that there will be no danger of the tank being overturned by a wind when emptied. In the event a tank is emptied, and there is any question as to sufficient anchorage provided, it is always a show of wisdom to guy the tank first.

Miscellaneous Items

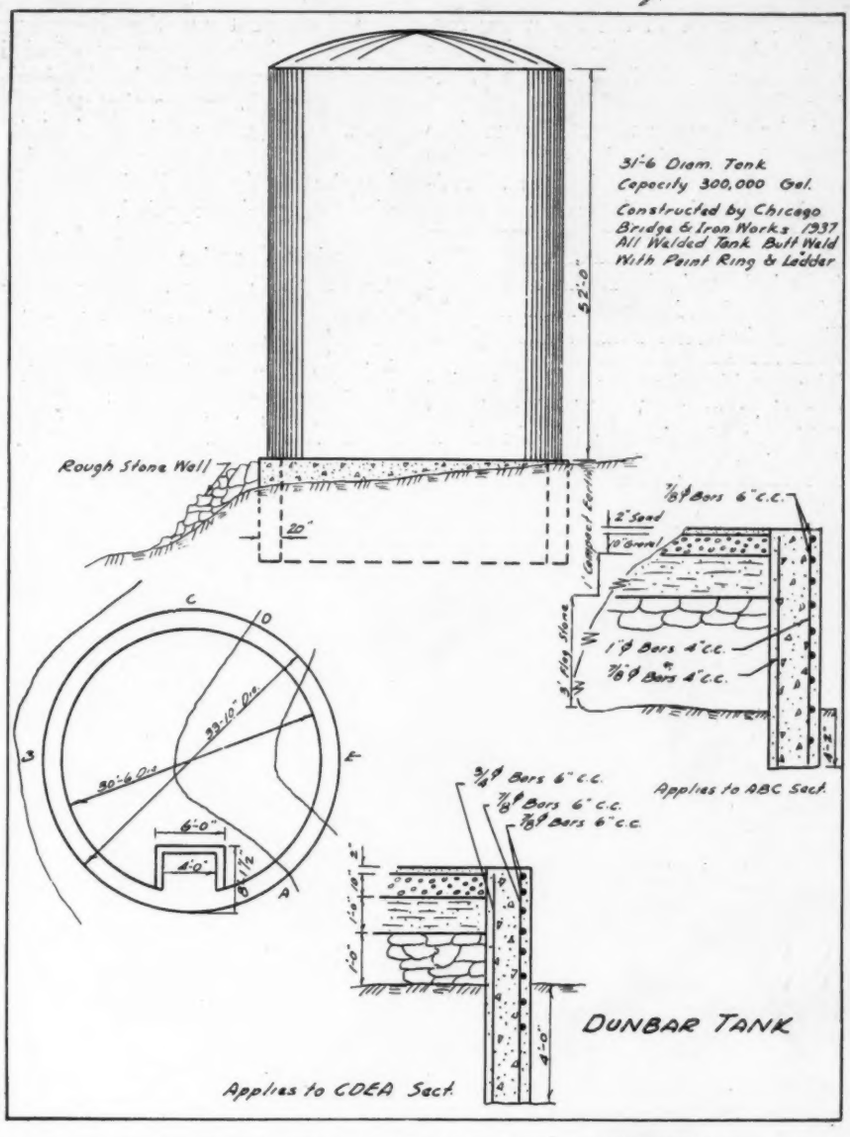
There should be provided on every tank an overflow of sufficient size to carry the water away in the event the control system should fail. The overflow line should be designed to preclude chokage or air binding. Landslides and damaged property are expensive items and there should be no risks in the design and maintenance of adequate overflow facilities.

Another very inexpensive item to be considered is a painting trolley. Rigging for cleaning and painting will be very simple with this adjunct provided, and the work can be done cheaper and safer. A trolley will save many dollars in later years.

In the shell of the tank, near the bottom, there should be a manhole of sufficient size to permit all material and equipment to pass when there is to be any cleaning or painting on the interior.

[It may also serve to save the lives of workmen as proved the case in a situation when a freshly coated tank caught fire in 1938.—ED.]

An outside ladder should be provided so that the height of water in the tank may be checked, and the interior inspected, at any time. Also, to permit the paint trolleys to be moved when there is work being done on the tank. If the tank is high there should be a safety-cage placed around the ladder and some provision made at the bottom to prevent its becoming an attraction nuisance. The lower section of the cage may be covered with fine mesh heavy wire and a hinged gate or trap door should always be kept locked.



Specimen, Design Sketch Which is Kept in Tank Binder With Inspection Record Sheets

Cleaning and Coating or Painting

The item of painting is last but surely not least important. This item may cause a great deal of discussion. Different waters will act differently on the interior of tanks and varied conditions of the atmosphere will affect the exterior differently. For a number of years we have used on our tanks prime coats of red lead and a sealer coat of aluminum paint. The results have been very satisfactory, but there are numerous coatings and paint producers who claim better results with other substances. Test specimens and time alone will prove the superiority of such substances. The 3,000,000 gallon tank previously mentioned in this paper was a very expensive tank and due consideration was given to the conditioning of the plates and to the painting. For

your information the following section taken from the specifications will show the decision on the painting.

"The plates are to receive one shop coat of red-lead and the water side of all plates two field coats of red-lead of the following mix:

Paste red lead	100 lbs.
Boiled linseed oil	1½ gal.
Fine powdered litharge	8 lbs
Turpentine	¾ gal.

The outside of plates are to receive one shop coat of red-lead and one field coat of red-lead of a mix of the following proportions:

Paste red lead	100 lbs.
Raw linseed oil	2⅛ gal.
Drier	1 qt.
Turpentine	1 qt.

The outside of the shell and roof will receive two field coats of Aluminum Graphite Paint."

We believe that this is the best paint job ever applied on any of our tanks and we are using these specifications on all new construction and also on maintenance jobs.

An Inspection System

At the present time we have 6 elevated steel tanks and 13 steel standpipes at our different plants throughout West Virginia. We use an inspection and report system that will enable us to keep a close check on the condition of these tanks. From the annual report of the plant superintendent on the forms provided, and from our personal inspection we provide in the budget for any maintenance that the tanks must receive. By this method it is also possible to keep a record showing the results obtained by the previous protection applied.

Cleaning Practice

The cleaning of a tank is by far the most costly item in tank maintenance. It is worse than useless to paint an improperly cleaned tank. It has been our policy to secure a good clean metal before any primer is applied. There has been some difficulty and expense in doing so, but our experience shows that an improperly cleaned surface will blister and peel within a year after paint is applied. We are using at the present time an Aurand cleaning tool, operating on compressed air, that has given fine results. This tool weighs but 7½ pounds and is not burdensome to those using it. It is composed of a rotary cylinder on which circular blades are loosely fit. These blades are replaceable, and it is also possible to replace these scraping blades with wire brush wheels. The tool can also be purchased to operate electrically. For further information the reader may wish to write the manufacturer, the following address being given for the purpose:

Aurand Mfg. & Equipment Co.,
Box 83 S. Y.,
Cincinnati, Ohio

The most expensive single item in cleaning is the tower legs on the elevated tanks. Due to the fact that the intricate lattice bars are spaced so close that it is difficult to clean properly with any form of tool. To properly clean a 35 foot tower leg costs approximately $45.00. With four or six legs, the cleaning cost of an elevated tank is unreasonably high. If we were to construct an elevated tank we would investigate thoroughly the possibility of using a single column for the legs. If this were not possible, a plate would be substituted for the lattice bars of a built up member. The cost of the additional weight of steel would certainly be classed as a credit to maintenance.

Accompanying this paper are specimen record sheets of tanks, such as we use for field work, maintenance estimates, and a general perspective of the tanks. These sheets, kept in a bound folder, serve to reveal a very useful case history on each tank and record the effectiveness of the type of maintenance given.

I should like to suggest that the "Standard Specifications for Riveted Steel Elevated Tanks and Standpipes," published by the American Water Works Association, be consulted by anyone thinking of future tanks. These specifications serve effectively as the base for more detailed specifications.

N.E.W.W.A. SPRING OUTING JUNE 28th

Popular New England "Ambassador of Commerce" Heads Outing Committee

"Reggie" Hayes

June 28th is the date set for New England Water Works Association's annual "June Outing"—The place, Swampscott, Mass., at the famed New Ocean House on the rock-ribbed coast about an hour's drive North of Boston. The "June Outing" of N.E.W.W.A. is the one activity of the Association when talking shop is taboo and everybody and his "best gal" (present or past) goes to have a big time.

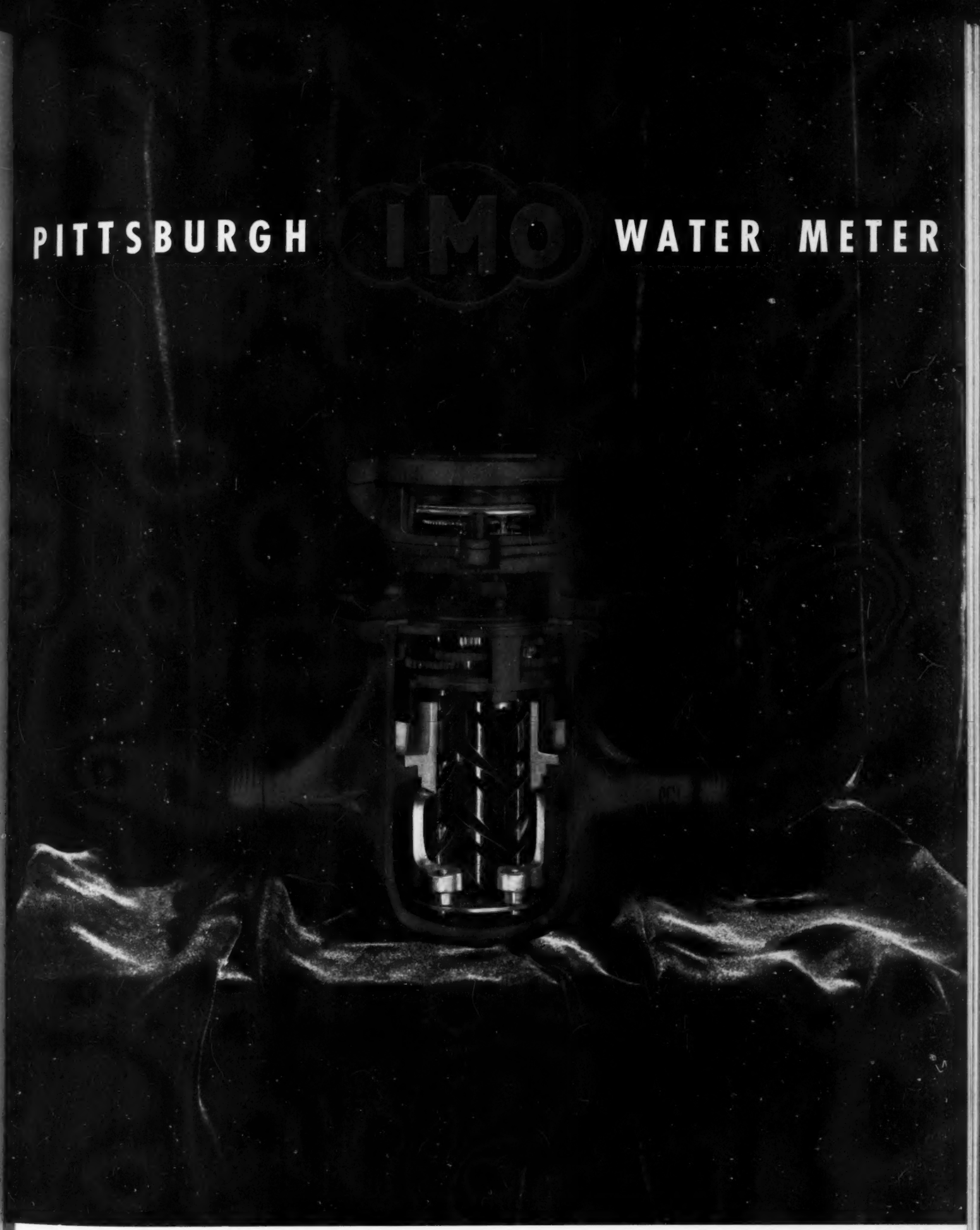
These outings are usually put in charge of one of N.E.W.W.A.'s popular "Ambassador's of Commerce" (manufacturers' representatives to some—peddlers to others) who picks his own committee. Selected to handle this year's outing is R. F. Hayes, Secretary of Hydrulic Development Corporation. (That's a nice sounding title, but "Reggie" pays for the kiddies' shoes by selling a little "Hydrotite" in between meetings.—Ed.)

MAYWOOD, ILLINOIS, HAS LARGEST ZEOLITE SOFTENING PLANT (A Correction)

Through a slip in typographical arrangement of the caption of the cover picture of the new Clarksburg, W. Va., Softening Plant on our April issue, the caption read—"America's Largest Municipal Zeolite Softening Plant." The original caption indicated Clarksburg's plant to be "America's Largest *Municipally Owned* Zeolite Softening Plant."

However, we now learn that even the qualifying phrase "Municipally Owned" is not correct, and that Maywood, Illinois, has within the year completed "America's Largest *Municipally Owned* Zeolite Plant," and deserves such credit. The Maywood plant has 6 units containing 5,000 cubic feet of greensand Zeolite with a reported capacity of 20,000,000 grains per regeneration. Clarksburg has 4 units containing only 50 cubic feet less of greensand, but the total capacity is only 14,000,000 grains per regeneration. We understand now that the latter is considered the criteron in comparing "size" of Zeolite plants, rather than the cubic footage or area of beds.

We stand corrected, and regret that we handed out the "ribbon" to Clarksburg when Maywood wins by a "nose" of 50 cubic feet, and a "length" of 6,000,000 grains.



MADE WITH ALL THE PRECISION AND ACCURACY OF A FINE WATCH

The Watchmaker Precision of the Pittsburgh IMO Meter Will Save Waterworks Men Thousands of Dollars . . .

YOU choose a fine watch to provide years of accurate time-keeping without the annoyance and expense of frequent repairs and adjustments. Why not apply the same reasoning to the purchase of water meters? Select meters designed and built to give years of sustained accuracy without the expense and inconvenience of frequent repairs and service interruptions. You can when you buy the Pittsburgh IMO.

Until the advent of the IMO Meter, the acknowledged need for sustained, trickle-accurate measurement could not be satisfied. A revolutionary type of meter was required. To build it required an entirely new manufacturing procedure, using equipment and materials never before adopted by any meter manufacturer.

Now, in the Pittsburgh IMO, watchmaker precision has been applied to water meter design and construction. Now, you can obtain a sustained accuracy in measurement previously unheard of. By using this meter, you can increase revenue thousands of dollars annually through measuring the volumes which previously trickled away in unregistered low flows. For example, one waterworks superintendent recently stated:

"We installed an IMO on a vegetable stand spray line where we never were able to measure this extremely low flow with a conventional type meter. Since installing your IMO, we have been able to collect as high as $5.50 a month. This meter paid for itself in a few months' time."

In the Pittsburgh IMO, an entirely new type of design results not only in performance impossible to duplicate with any other type of meter, but also in sustained accuracy for years to come. *Pittsburgh IMO Meters Wear In Where Others Wear Out!* The sustained accuracy of this meter has been proven in any number of instances. In one specific case where after 3,000,000 gallons had been measured in an impartial test, the meter was torn down and checked with micrometers and calipers. Only infinitesimal wear was evidenced. The meter tested slightly better on the low flows than when first put in service and accuracy had not changed at rates of flow above one gallon per minute.

In addition to the increase in revenue gained through accurate measurement of large and small flows alike, maintenance costs go down with the IMO Meter. This saving results from the unique design of the measuring chamber and its operating rotors. The rotors revolve with a semi-floating action and water flows through the measuring chamber in a straight line, without any turbulence. This design principle greatly increases the life of the working parts as compared with conventional meters and insures longer, trouble-free service.

The Unique Measuring Chamber of the Pittsburgh IMO Meter—Responsible for the Accuracy and Long Life

The accompanying illustrations show the fundamental elements which are responsible for the accuracy of the Pittsburgh IMO. These consist of three screws which mesh with each other and fit the bore of a casing. These screws are called rotors while the surrounding casing is the measuring chamber. Water enters the measuring chamber from the bottom and, as it is forced upwards by line pressure, causes the rotors to turn from its path. They rotate and are propelled by the surrounding medium (water) in a perfectly continuous flow. The threads on the rotors act as a continuous piston, which always moves in a forward direction. The center rotor is known as the power rotor and performs the function of driving the register through the oil enclosed gear train. The two side rotors are known as idlers, doing no work but serving as seals for the power rotor. They rotate in the opposite direction to the power rotor. Water is not brought into rotation but flows smoothly without turbulence. There is no pulsation whatsoever. The action is, therefore, smooth and free from vibration, even when operating at its maximum rate of flow.

The measuring chamber is cast from a special non-corrosive nickel bronze alloy. Machining the bore is held to extremely close limits and the polished interior surfaces provide an ideal confining medium for the rotors.

The three rotors are carefully machined from vulcanized hard rubber. Hard rubber provides necessary lightness, plus strength and resistance to wear, and is the one material best lubricated by water.

Although the IMO is practically self-cleaning, a circular mesh strainer of 20 mesh monel metal wire completely encircles the measuring chamber and prevents large particles of foreign matter from reaching the working parts. The IMO Strainer presents more area than that used in any other meter—in fact, it has over 500% more screening surface than in some disc meters. It should be observed, however, that the IMO will stand up longer and better than any disc meter, even if the strainer is omitted entirely because the water passes through the measuring chamber without turbulence.

Get the whole Pittsburgh IMO story. Write for Bulletin W-529.

PITTSBURGH EQUITABLE METER COMPANY

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SOME NEW DEVELOPMENTS IN SEWAGE TREATMENT IN HOLLAND*

WILLEM RUDOLFS[1] and H. KESSENER[2]
America Holland

FOR many years mandatory rules and regulations for abatement of stream pollution, and for the treatment of sewage and waste, have been supplemented by technical assistance and advice from the Government of the Netherlands. In furtherance of this policy there was created a Water Pollution Board and an Institute for waste purification, charged with the duties of detailed investigations of actual conditions, formulation of plans and procedures to abate pollution and to give advice to municipalities and industries pertaining to the best and most economical methods of sewage and waste treatment. This in turn has led to extensive experimentation involving existing methods, and the development of new devices. The earlier work, begun in 1910, was primarily concerned with industrial waste treatment, but since 1920 the whole field has been taken into consideration.

In the company of the energetic junior author, the senior author had an opportunity on a recent visit to Holland to see several of the new plants and to pay particular attention to new and novel design features, as well as to operating results.

The Hilversum Works

One of Holland's more interesting plants recently placed in operation is at Hilversum. The plant consists essentially of screens, detritors pre-settling, digestors, brush aeration tanks, final settling tanks and sludge drying beds. The plant is designed for a population of 40,000 with a dry weather flow of about 1.2 mgd. and a maximum wet weather flow of about 4.5 mgd. The connected population is 36,000. The clarifiers have a detention period of 2.25 hrs. with dry weather and ½ hr. at maximum flow. The aeration tanks provide for 14 hours detention under dry weather conditions, while the detention time in the final settling tanks (Dortmund type) is 1½ hours. The sewage is strong, containing large quantities of textile, dye, fish and chemical wastes from a variety of industries. It enters through a central riser tube and is distributed through various channels (Fig. 1). This method appears to give good distribution without difficulty of solids settling in the channels. The aeration units are of a somewhat conventional type. In the Kessener system employed brushes rotate at 68 rpm. causing excellent aeration and considerable wave action (Fig. 2 and 3). The results obtained are as follows.

	B.O.D.	O.C. 10 min.	NO_2+NO_3
Settled sewage	324	125	—
Final effluent	15	26	7.6

This degree of purification is obtained with a power consumption of 27.75 KW per million gallons of sewage.

Multi-Stage Digestion

The digestion system consists of three-stage digestion. In the first tank the fresh solids are seeded, mixed, heated and kept for about 24 hours or longer, as the requirement may be. In the second tank primary digestion takes place. The third tank is provided for after-digestion and sludge storage. Gas collection is from tanks I and II; the gas being used for driving the aeration brushes, sludge return mechanisms and for laboratory needs. Of considerable interest is the supernatant overflow placed at the end of the third tank. Since active digestion preceeds passive digestion in the third (storage) tank, thus allowing sufficient time for separation of the liquor from the sludge, the overflow liquor is clear with little suspended material and relatively low B.O.D. Use is here made of the well-known principle, that settling and compacting of sludge is a function of time and original concentration of sludge. The type of rectangular digestion tank with inlets and outlets far apart undoubtedly aids the performance.

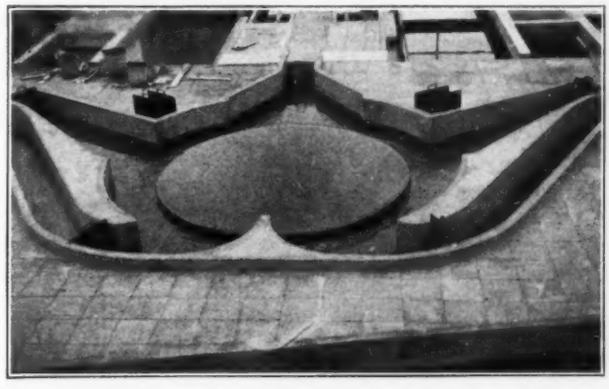

Fig. 1—Distribution Scheme of the Primary Tanks at Hilversum.

Unique Sludge Heating

The heating and mixing of the sludge in the first tank is performed in one operation. Hot water coils (Fig. 4) are placed on a hollow rotating shaft, allowing gentle mixing of the fresh solids with the ripe sludge added for seeding. Efficiency is increased and heat losses reduced. The digesters are equipped with square floating covers developed by Kessener in 1915 at Oude Pekela (Holland) in digesting wastes from straw paper manufacture. To start the digesters, use was made of a small quantity of ripe sludge and some calcium acetate. On the fourth day after starting some 920 cu. ft. of gas was delivered to the gas holder and gasification proceded at an accelerated rate without any troubles of sludge turning acid or foaming. The sludge is heated to about 32 deg. C in the smallest tank and is then discharged into

*Journal Series paper N. J. Agricultural Experiment Station, New Brunswick, N. J., Dept. Water & Sewage Research.

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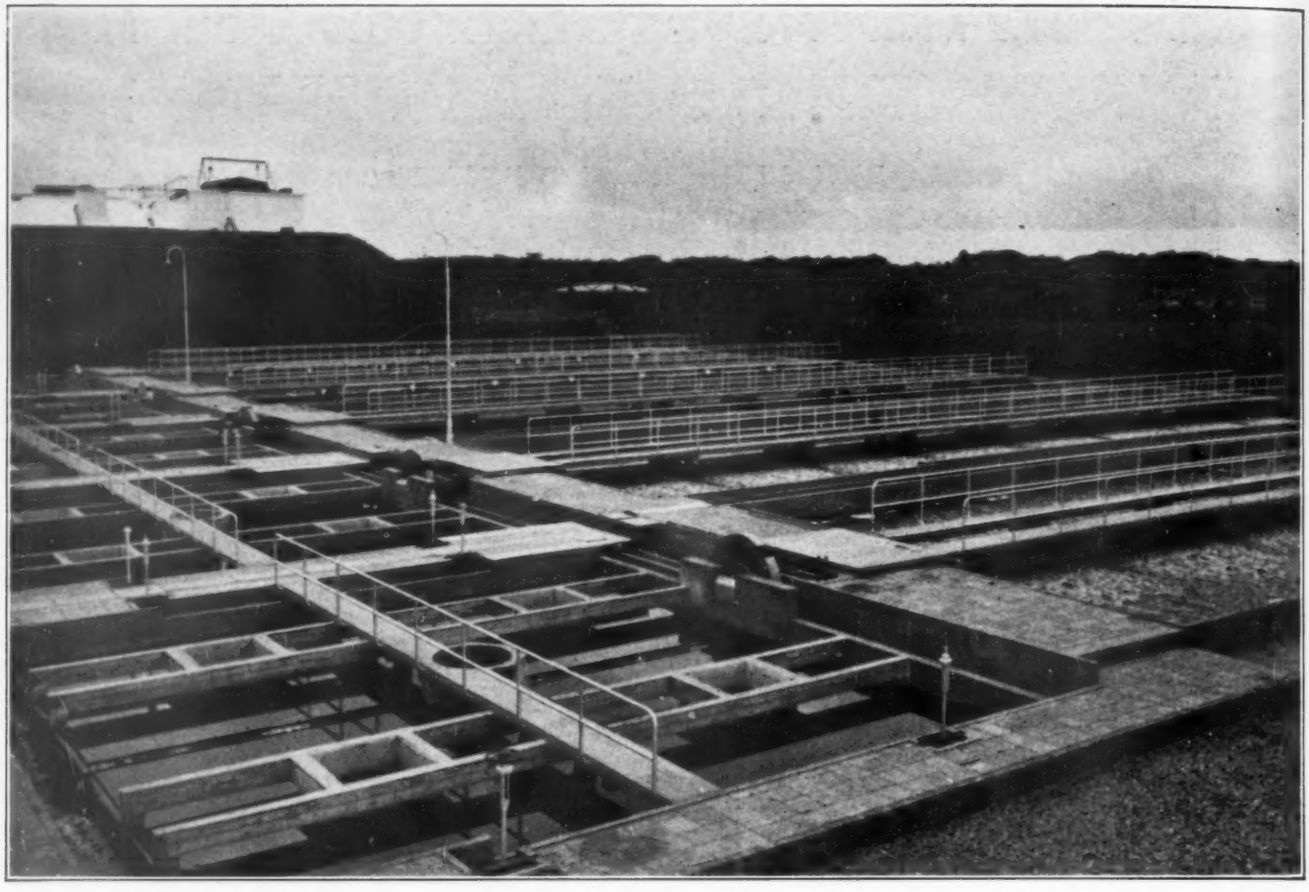


Fig. 2—The Plant of Hilversum.

Brush Aerators (right); Digesters (left background); final tanks (foreground). Note the row of paddle (bucket) wheels at inlets to the final tanks. These return sludge proportionately and automatically.

the secondary tank. The pH of the sludge has remained practically constant at 7.3, increasing gradually in the after-digestion tank to 7.8.

Aeration Brushes Improved

The brushes Kessener used for aeration were originally constructed with a wooden center and long fibre bristles. By considerable experimentation brushes were developed consisting of a rustless steel axis and narrow, thin plates. Eight rows of thin shell tapering combs, (0.6 mm. thick and about half an inch wide at the base and about 7.5 inches long) are caulked cold with a hammer in lead, and placed in slots of the axil. These thin blades are very flexible, have a long life and can be easily replaced, if necessary.

The aeration units are very flexible; aeration can be increased or decreased at will; inlets and outlets can be raised and lowered to allow deeper dipping of the steel brushes, which ordinarily dip about ½ inch into the liquid. This provides for considerable spray and excellent wave action, causing the surface area of the liquid to be increased several times for greater oxygen absorption and at the same time requiring relatively low power.

Novel Sludge Return System

Activated sludge at this plant and others is returned by means of water wheels (Fig. 2) which allows any given quantity of sludge to be returned merely by raising or lowering the depth of the sludge in the return sludge channel, so that increased or decreased quantities of sludge are scooped up by the wheel as it slowly rotates. In addition to returning any desired volume of sludge the water wheel prevents breaking up of floc, because the sludge is gently scooped up and deposited at the surface of the incoming sewage.

Of interest was the neat and effective way of planting the steep slopes around the digesters to prevent gullying—(Fig. 2). Plantings observed at different places include weeds, grass, honey suckle, barberry, laurel and vinca. At Hilversum the banks of the digesters are covered with Juniper, which gives a pleasing dark green effect throughout the year.

Flocculation and Settling Aid

Considerable success has been obtained through the addition of talcum venetum to the aeration tank when the process was started. This aided in rapid floc formation and helps activated sludge to settle readily when the mass is fluffy.

A novel method of determining the rate of settling of concentrated activated sludge and determining within one or two minutes whether the sludge is in a good condition to settle is practiced at Hilversum. A given volume of activated sludge is put in a liter cylinder filled with tap water. Good settling sludge passes rapidly through the tap water and forms a dense layer at the bottom, while poorly settling sludge remains dispersed in the water.

The cost of this modern plant was 370,000 guilders, equivalent to about $250,000.

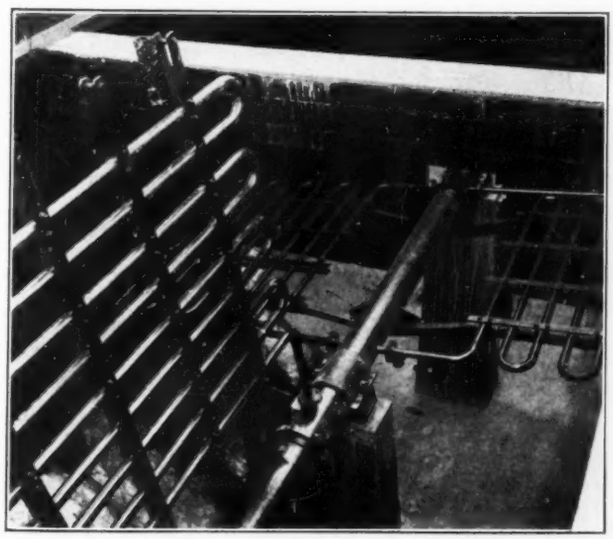
The Bussum Works

Another activated sludge plant placed in operation during the last year is at Bussum. This plant (Fig. 5), located at the end of a city street and surrounded by dwellings, takes care of the waste of a population of 10,000. All the sewage passes a cage screen and is pumped into a vertical self-cleaning grit chamber located inside a building. The sewage passes through three Imhoff tanks used for settling; the settled sludge is pumped to a digester and the liquid is aerated in two aeration tanks. The 350,000 gallons of sewage comes from a combined source. Treatment is given 3 times in the dry weather flow and the storm water in excess is treated in a tank equipped with automatic scrapers. Into the rectangular grit chamber vertical walls of different heights are built allowing the same velocity of flow with varying flows. The construction is somewhat along the lines of the Blunk grit chamber, but of original design. Compressed air removes the accumulated grit, which contains a low percentage of putrescible material.

The aeration tanks (Fig. 6) are equipped with brushes on the sides of the two tanks. Cross walls prevent short circuiting. At the time of visit the return sludge was thin, requiring a considerable volume to be sent back to the aeration units. With a simple adjustment the water wheel returns any volume at will.

The supernatant liquor from the heated Dorr digester is treated with lime to prevent spoiling of the activated sludge. The lime is mixed automatically with the supernatant. An interesting automatic flow measuring device and diversion channel system (Fig. 7) is located outside the grit chamber. Gas production amounts to 1.1 cu. ft. per capita.

The degree of purification obtained at the plant is high as indicated by the results shown in Table 1. In spite of the strong settled sewage handled the average B.O.D. reduction amounts to 97 per cent. Of particular interest is the high ammonia reduction (76 per cent) and the high average nitrification. High removal of ammonia and good nitrification is considered necessary because of the subsequent use of the receiving stream. Off-hand it would seem that such high nitrification is unnecessary and considerable power could be saved. Despite such high purification, power consumption at the plant amounts to only 14.75 KW per million gallons of sewage.



Combination Sludge Agitator and Heating Mechanism in First Stage Digesters of Hilversum.

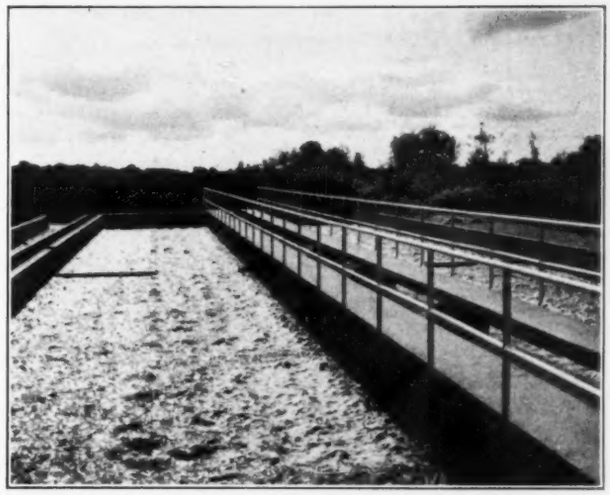


Fig. 3—A Splendid View Down the Kessener Revolving Brush Aeration Units.

Note the efficiency producing turblence and wave effects in combination.

Vugt's Automatic Plant

The town of Vught, with an ultimate population of 25,000, has constructed a new treatment plant consisting of two-story tanks for pre-settling, Kessener surface aeration system, final settling tanks of the Dortmund type, separate digesters equipped with horizontal mixing and heating apparatus (utilizing the gas for heating and power for the shafts to run the aeration apparatus) and sludge beds. The plant is built in four distinct units. At the time of the visit one unit was in operation to take care of the 5300 connected population and the waste of 5 power laundries. Laundry waste is of considerable importance in this town, the volume on some days may be the same or more than the domestic sewage. The plant treats the sewage and waste from a separate sewerage system. Of considerable interest is the fact that the plant is entirely automatic. One man comes on Monday mornings to take meter readings, to oil the machinery and draw sludge from the digesters, if needed. The surface aeration (Kessener's brushes again) is very effective and the effluent produced is crystal clear. The overflow baffles for sludge return to the water wheel, consist of small iron rods placed on top of each other. By removing the ¼ and ½ inch rods to suit, the volume of the sludge to be returned is regulated. Measurements of the power required for the effective agitation and aeration amounted to 185 watts per meter of brush length or about 12 watts per cubic meter of aeration tank capacity.

Digestion and gas collection with floating covers is of interest, because the gas storage tank directly connected with the digesters acts as a balancing unit. When sludge is drawn from the digesters gas from the holder displaces the volume of sludge drawn, preventing air from entering the digesters and possible tipping, buckling or collapse of the rigid floating covers. Gas burners, flame traps, pumps, and large motors are housed in a compartment next to the digesters and the motors, and driving gears of the water wheels are covered with sliding covers

which lock. Similar covers appear in Fig. 2 in front of the sludge return wheels.

Average results obtained at the plant show a B.O.D. of 300 ppm. in the settled sewage and 15 ppm. in the effluent. Samples of sewage and effluent taken at about the time of the visit showed in ppm.

	Settled Sewage	Effluent
B.O.D.	300	12
NH_3-N	74	30
O.C. (10 min.)	121	43
N_2O_3	—	33
N_2O_5	—	16
pH	7.8	7.9
Meth. Blue	—	98

As stated before, the effluent was transparent, no fine particles of sludge being present, purification being accomplished with 4.2 KW for the 151,000 gallons of sewage and laundry waste. The strength of the sewage can also be gauged by the fact that the flow amounts to but 30 gal. per capita, with all laundry waste included. Previously the senior author has reported the results of a small institutional activated sludge plant in Holland operated mechanically, but this appears to be the first municipal activated sludge plant operated by remote control and persistently producing a high grade effluent at low cost. The construction cost of the plant was 58,000 guilders, equivalent to about $32,250.

Economical Chemical Treatment

Chemical treatment of industrial and mine wastes practiced at several places had pointed the way to treatment at Tilburg, where most of the sewage consists of textile, dye and chemical wastes. The plant consists of coarse screens, grit chambers, brush pre-aeration, mixing and settling tanks, sludge treatment tanks and sludge beds. The plant is able to treat twice the normal dry weather flow. Pre-aeration of the sewage for 20 minutes is sufficient to eliminate the hydrogen sulfide and render the sewage more amenable to chemical precipitation. After aeration the sewage is agitated and treated with a solution of 1 per cent commercial alum. The dosage amounts to about 35 ppm. Aluminum flocculation is effected with wooden paddles, turning at 1 rpm., to prevent breaking of floc, and retained for 12-24 minutes, depending upon the sewage flow. A rather nice, well settling floc is formed. The treated sewage is settled in a Dorr Si-feed clarifier for 2.5 to 5 hours, producing a sludge of about 2 per cent density. The sludge is treated with sulfuric acid to recover the alum, by adding about 100 grams 60° Baumé H_2SO_4 to 1,000 gallons of sludge. It has been found that a sludge concentration of about 2 per cent is best to work with. After mixing the sludge with sulfuric acid the mixture is left standing for about 3 days. This gives a good separation of clear liquor, which is again used for coagulation. The sulfuric acid treated sludge is washed with water to recover more alum, and about 80 per cent of the original alum is thus recovered. The washed sludge condenses to between 6 and 7 per cent solids and is placed on drying beds for a period of 6 to 8 days. Cracking begins after 2 days. The filter media of the drying beds (25 inches thick) consists of three layers of graded cinders. Water from the under-

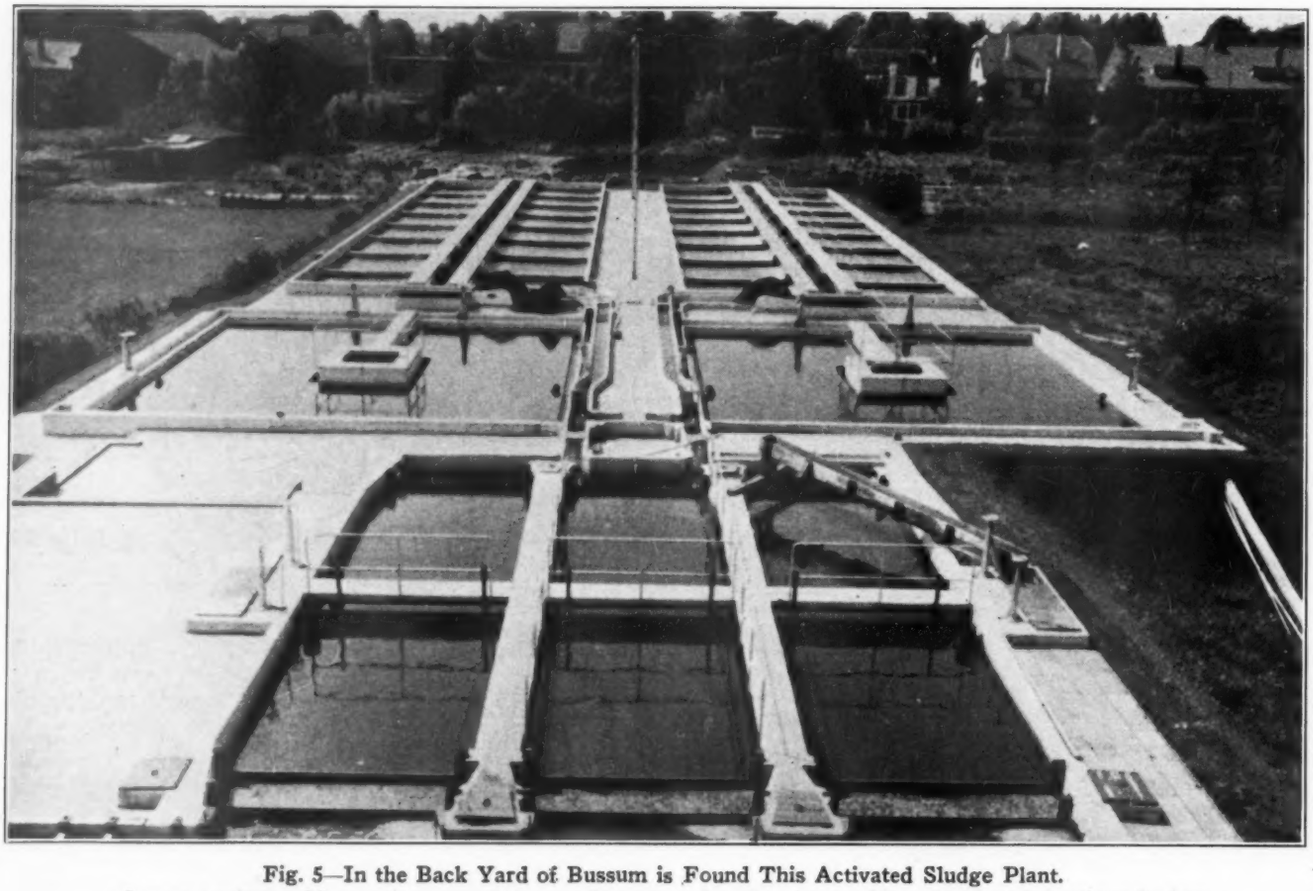


Fig. 5—In the Back Yard of Bussum is Found This Activated Sludge Plant.
It must perform without nuisance, and because the sewage is only minutes old at the plant it consistently does.

drains is returned for use in making up the 1% alum solution, because it contains some alum. The dewatered sludge is *non-putrescible* and is used for fill. Experiments are being made, looking toward rendering the sludge of value for agricultural use.

Also at Tilburg two experimental activated sludge units, capable of treating about 100,000 gallons each, have been installed. These units are very flexible, can be run together or as separate units, treat settled or chemical treated sewage alone or in combination, varying only one factor at one time. The variable factors such as volume of sewage, degree of aeration, volume of return sludge and density of return sludge can be regulated. One tank may receive raw and another chemically treated sewage. The sewage and return sludge can be fed into different parts of the aeration tanks, together, alone or in several inlets. Thereby, it becomes possible to utilize a part of the tank capacity for pre-aeration of the sewage, chemically treated or untreated as requirements may dictate. Also, by feeding the aeration units at several places at once, debilitating oxygen depletion at the usual critical point can be avoided. The units are equipped with the regular mechanism (rustless steel combs) for aeration, reaeration and return sludge as well as automatic water and electricity meters, continuous regulating overflows and apparatus for automatic sampling. By varying the depth of the combs into the liquor the degree of aeration is regulated.

Combination Treatment

Of considerable interest is the fact that this chemically treated sewage—waste mixture can be readily treated by the activated sludge process. The flow across the aeration tanks can be varied. When moving at a velocity of about 9 feet per second across the tank white-caps are formed, producing very effective aeration. For chemically treated and settled sewage about 3.5 hours aeration is required to reduce the B.O.D. from 166 to 8 ppm. The whole plant is also impressive from the standpoint of flexibility of the Kessener aeration scheme, from the simple device of lowering the brushes to the method of feeding and withdrawing sewage and sludge.

A comparison of results obtained by settling alone, settling and chemical treatment, settling and activated sludge treatment, and chemical treatment followed by activated sludge is given in the following figures, expressed in parts per million:

	Turb. %	B.O.D. 5 day	O.C. 10 min.	NO_2NO_3	pH	% B.O.D. red.
Raw sewage	73	528	267	0	7.7	—
Settled sewage	60	352	199	0	7.8	33
Chemical treatment	13	158	81	0	7.0	70
Settled sewage treated by act. sludge*		11	21	0.3		97.9
Chemical treatment and act. sludge†		10	16	0.6		98.1

*aeration period 7.2 hours. †aeration 3.2 hours.

It is evident that settling alone and chemical treatment produced the usual B.O.D. reduction obtained

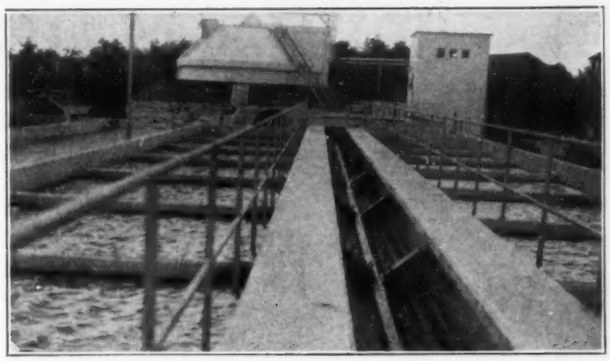


Fig. 6—Aerator Brushes and Return Sludge Channel Center at Bussum.

(In left rear are the digesters; right rear is chemical dosage equipment for supernatant treatment or odor control if required.)

in the this country with weaker sewages. The high degree of purification accomplished by activated sludge after settling (97%) is of interest only because it shows that the large amount of trade waste present does not interfere with the production of a highly purified effluent, and the non-necessity of having a high degree of nitrification. The point of particular interest, here, is that the chemically treated sewage, (where a much greater portion of the B.O.D. is removed than by settling alone) could be purified in less than half the aeration time required for the settled sewage. This raises the question of whether a combination of this type of chemical treatment and activated sludge is more economical than plain settling and activated sludge, inclusive of treatment and handling of the resultant sludges.

[During recent years considerable experimentation, leading to the construction and operation of units of particular interest, has been conducted in Holland under guidance of Dr. Kessener. These experiments and newly developed units include closed and open trickling filters, high rate filters, treatment of trickling filter effluent by activated sludge, effective mixing and scum breaking devices in digesters, determination of aeration capacities, etc., some of which are to be the subject of another article, planned for a future issue.—Ed.]

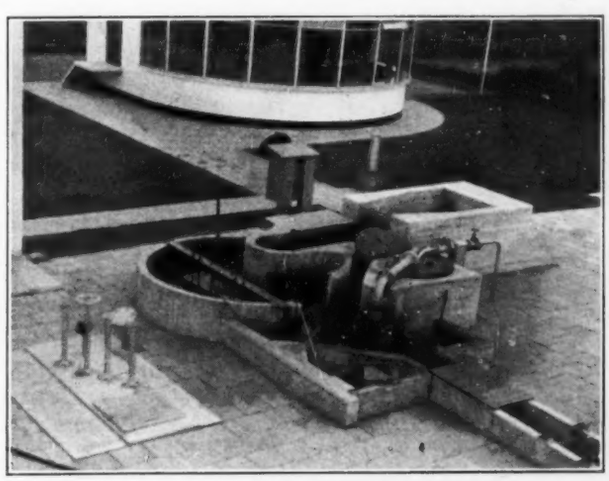


Fig. 7—Automatic Measuring and Flow Distribution Device at Bussum.

SEWER MAINTENANCE

By JOSEPH H. LeCHARD
Chief Engineer,
The Atlantic City Sewerage Co.
ATLANTIC CITY, N. J.

The Author

This article has been too modestly captioned. It might more descriptively have been captioned "Modern Practices in Sewer Maintenance Pays Dividends," for that is what has proved to be the experience of the Atlantic City Sewerage Company.

We have asked Mr. LeChard to contribute this article for three reasons. First; because his company is America's most important and successfully operated privately owned sewerage utility. Second; because the author, as a superintendent looking toward better service and improved public relations, has established an effective system of sewer maintenance. Third; because Mr. LeChard, as an engineer-manager looking toward economy in operations, has proved his convictions that time and labor saving methods have justified expenditures for modern mechanized equipment, productive of lowered maintenance costs.

Along with it all has been realized a reduced hazard to members of the sewer maintenance crews and reduction in complaints arising from dirty sewers. Out of this story comes proof that "horse and buggy day" methods are proving as uneconomical in sewerage practice as they are in water works practice.

SINCE this article concerns itself with the cleaning and maintenance of the collecting sewer system of Atlantic City certain facts of a general descriptive nature should be stated. The city covers an area of approximately fifteen square miles with very little variation in its surface elevations. The Atlantic City Sewerage Company, which is a private corporation, owns and operates the separate type sanitary sewerage system which is composed of approximately one hundred miles of sewers, ranging in size from eight inches to seventy-two inches in diameter. While the permanent population of the city is 70,000, it is estimated by reliable sources that 15,000,000 people visit it annually. In consequence, the average daily flow ranges from nine to eighteen million gallons daily.

Cleaning operations on the system are divided between two organizations, each of which has its particular work to perform, and special equipment to use in such performances. One is charged with maintenance of house connections; the other, with street sewers.

The House Sewer Crew maintains and cleans all house connections, and is required to supply prompt and courteous service at any hour—day or night. The operation of this crew will be discussed later in the article. The Street Sewer Crew works only during the day time, having their schedule of cleaning operations planned to cover the entire system at least once during the year.

Street Sewer Operations

The Street Sewer Cleaning Unit consists of a crew of three men, two of which operate power cleaning machines and the third acts as a general utility man. A well equipped tool and equipment house, mounted on wheels, accompanies the cleaning unit on its course through the city streets. The cleaning machines are towed to and from the job every day, but all of the other equipment such as sewer buckets, brushes, cable sheaves and hand tools are stored in the equipment trailer on the job.

The Cleaning Machine

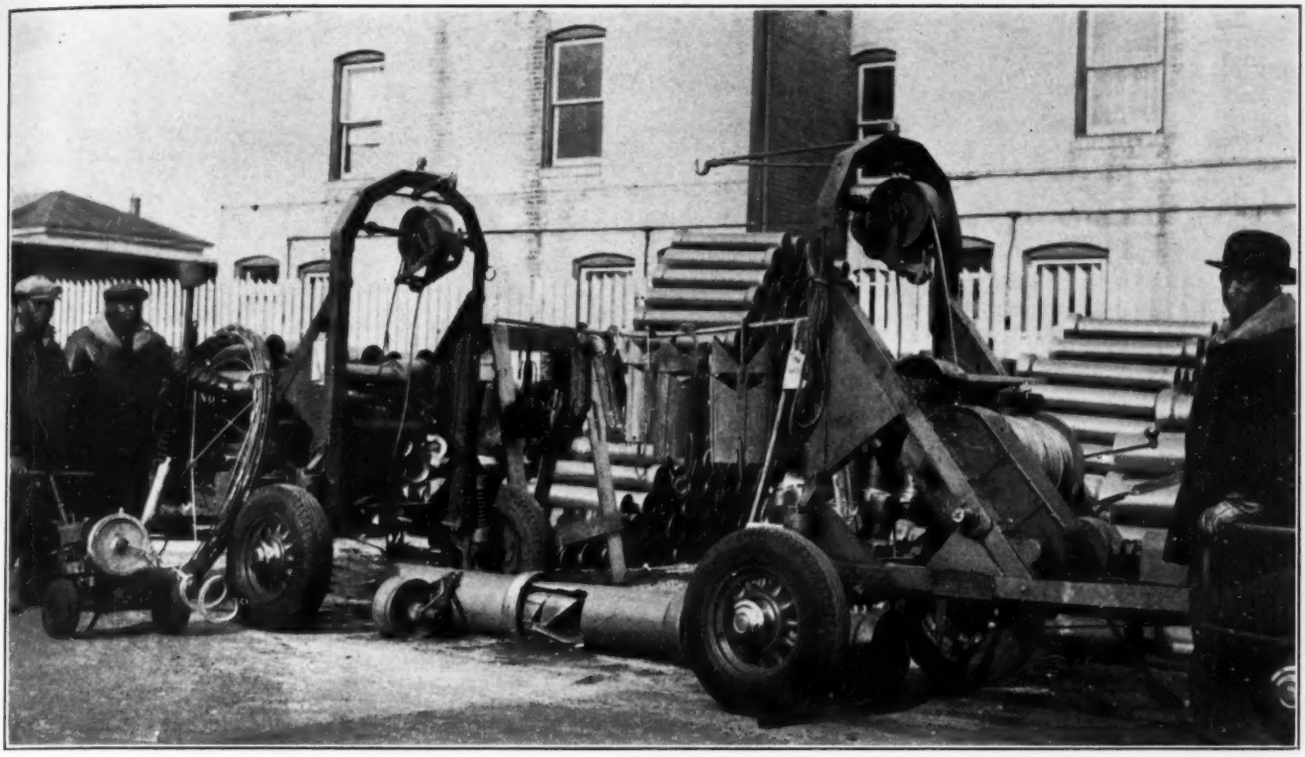
Before describing the operations of the street sewer cleaning crew, the four outstanding features of the Champion Power Cleaner employed should be stated.

First of these is the Kuhlman Expansion Bucket which bites into the blockade, fills itself, and on the reverse pull, its jaws snap shut, securely holding the load. The filled bucket is hauled to the street level, hoisted to the boom hook where its jaws automatically open and the bucket simultaneously expands to 110% its normal size. The expanded bucket easily releases the load to the street to be hauled away.

The second feature is the automatic safety clutch which is an ingenious linkage between the knee-action wheels and the clutch lever and becomes active instantly upon overload. This can be set at any pre-determined tension. As soon as the overload occurs due to the bucket in the sewer striking an immovable object, the cable compresses the springs, which in turn trip the clutch, thus relieving the cable pull. The saving in cable replacement cost, due to broken strands and the elimination of strains on the entire equipment, makes this automatic clutch a very desirable feature. If the bucket, in its course through the sewer, strikes an uneven joint or some unmovable object in the sewer the automatic clutch also saves the sewer from harm. The machine is equipped with hand crank handles which can be used to free a bucket, should it be necessary to do so, by working the bucket back and forward by manpower.

The third feature is the level-wind attachment on the cable drum which causes the cable to be reeled and unreeled with utmost precision, in perfectly paralleled coils, exactly side by side. As a result there is no chafing or jamming due to one coil being wound on another, and this adds materially to the life of the cable. Anyone who has seen cable wound unevenly on a drum, can appreciate the value of this service.

The fourth feature is a secondary "free wheeling" clutch on the cable drums. This auxiliary clutch is always in use when unreeling the cable into the sewer while the bucket drawn by the second machine at the other manhole, is taking its load. It entirely disconnects the 20 to 1 reduction gear train that connects the



Our Twin Champion Power Cleaners and Flexible Rod Power Drive Unit. (left)

The three huskies comprise our street sewer crew. The mobile tool and equipment house which travels with the cleaners does not show in the picture.

cable drum to the motor. Thus the 8 inch drum, with a 750 foot cable capacity, revolves freely on its own axle, conserves power and eliminates wear and tear, incident to running high reduction gears in reverse direction. This clutch is put into engagement with a flip of the hand and released with a slight wrist movement that automatically locks it in open "free wheeling" position. The power unit used on these machines is a 5 to 7 H.P. LeRoi enclosed gasoline engine. An accompanying photograph shows the cleaning machines and some of the buckets and brushes used.

Machine Operation

After the machines are placed in position over their respective manholes the lids are removed. A light cotton cord, such as is used in sewer construction for grade lines, is then carried through the sewer by the float to which it is attached. After the cotton cord has been passed between the manholes it is used to draw through the sewer a small 3/16 inch cable which is wound on a small hand operated drum which is mounted on each machine. The 3/16 inch cable is wound back on the drum by the machine operator, bringing with it the half-inch cable which is wound on the power-driven drum. Just a few minutes are necessary to connect the expanding sewer bucket, of proper size, to the cable connecting the machines. While the machine operators have been threading their machinery, so to speak, the third man has clamped the cable guide wheels in position at the bottom of each manhole, and the sewer cleaning operation is ready to start. The bucket is drawn through the sewer against the flow until it has a full load and is then drawn back, emptied, and started on another trip. This process is continued until the full length of the stretch of sewer between the two manholes has been traversed. The bucket is then removed and a circular wire brush, which snugly fits the sewer, is attached and pulled through the sewer by the power drums. This wire brush removes grease particles which may have been clinging to the top of the sewer out of reach of the bucket. After the brushing operation has been completed the machines are disconnected and one machine is moved so that the stretch of sewer immediately downstream may be cleaned.

When conditions are such that the float can not be used, as a means to carry the cable through the sewer, such is accomplished by the use of inter-locking sewer rods 3½ feet long. Once these rods are placed in the sewer they may be pushed from manhole to manhole, without being disconnected, for several city blocks until the end of a sewer or an angle point is reached. If necessary these rods are anchored in the sewer overnight so they will be in position when needed the following day. Our vernacular term applied to this operation is "walking the rods" and it is a time saver where long mains, which are flowing too full for the use of floats, have to be cleaned.

Flexible Rod Work

Upon occasions when the street sewer becomes completely filled with sand, or tar, a special set of equipment is used for cleaning. Augers of the proper size are attached to jointed "Flexible" Sewer Rods and these are rotated in the sewer by the "Flexible" Power Drive operating on the street above. This rotary and lateral pressure is transmitted in corkscrew fashion to the auger through the flexible sewer rods (seen coiled in the pictures) by pushing the machine, which is mounted on two wheels, forward and backward on the street along the line of the sewer. The use of this equipment often eliminates the necessity for digging up sewers to remove stoppages.

House Service Operations

Experience has proven that customer goodwill can be built up

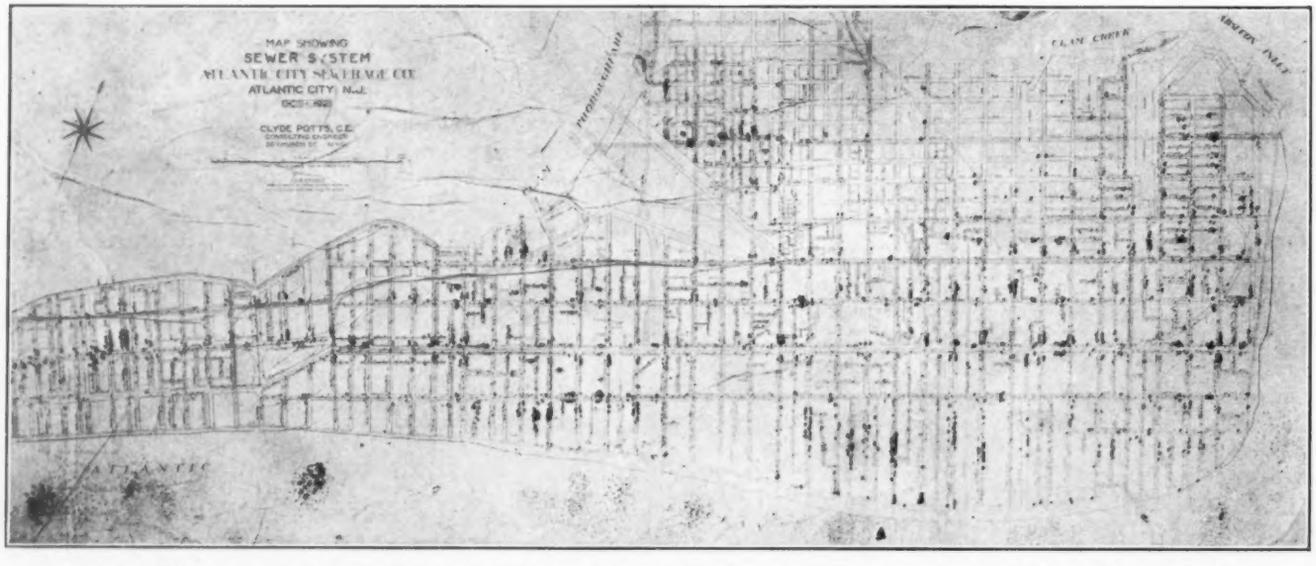
quicker by prompt and courteous attention to house service or stoppage calls, than any other way. For this reason we maintain a completely equipped light delivery truck always ready to reach any section of the city within *one-half hour* from the time of notification of stoppage. A photograph of this truck with most of the equipment carried is shown. It includes all sorts of hand tools to remove foreign objects from traps and sewers. Should the stoppage be caused by presence of roots an auger attached to flexible sewer rods is turned by hand to make the removal. Stoppages caused by presence of sand are also cleared with this equipment. The most common stoppage is caused by accumulation of rags and grease. The most effective tool for clearing this type of stoppage in a house sewer is a fifty-foot length of quarter-inch diameter steel wire. The end which is placed in the sewer is bent up for a distance of six inches and as this is directed into the stoppage it receives a spiral motion generated by the cranking action on the other end of the wire.

Our Company is responsible for maintenance of service in the house sewer from the main to the double handhole trap located just inside the curb line. The owner is responsible for the plumbing lines from the house to the curb. We have a working agreement with the Master Plumbers' Association of our city, whereby we will not encroach on their territory as representatives of the property owner, and they in turn will not concern themselves with our part of the house connection. The responsibility in each particular case is easily determined by lifting the removable lids from the trap located at the curb. (One of these traps is pictured with the service truck.) If inspection reveals that the sewage does not drain properly at this point the task of remedying the condition is ours. On the other hand, should the drainage be proper the plumber looks for the trouble on the customer's side of the curb trap.

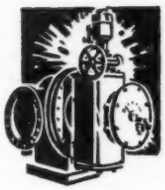
One of the House Sewer Service Trucks and a Variety of Clean-Out Equipment
This truck and crew is subject to 24-hour duty in responding to customer calls or complaints within 30 minutes.

As each stoppage is cleared and the crew returns to the office, a pin is placed on a map of the system to mark location of the stoppage. The head of the pin denoting a stoppage in the street lateral is of a different color and size than that marking the point of stoppage in a house sewer. At the end of each year a photograph is made showing the location of the stoppages. This method provides an excellent record, showing at a glance the bad spots which develop from year to year. The cause for the trouble is ascertained and corrected if possible. A copy of one of these record photographs accompanies this article.

A daily record is kept by the foreman of the street cleaning crew showing the date each stretch of sewer is cleaned and the amount of solids removed. Cost records, broken down for labor and supplies, are kept. The average unit cost for cleaning our entire system of varying size sewers has now been reduced to seven cents per foot. Such can be credited to the employment of modern equipment and tools; and thereby the more efficient use of labor and manpower.



A Record Photograph of One of the Annual Spot Maps, Showing Stoppage Locations and Complaints Received



APPRECIATING that the Convention will make heavy demands upon your time, we content ourselves with making one suggestion—Don't purchase new Valve Equipment, until you have sent for and thoroughly examined

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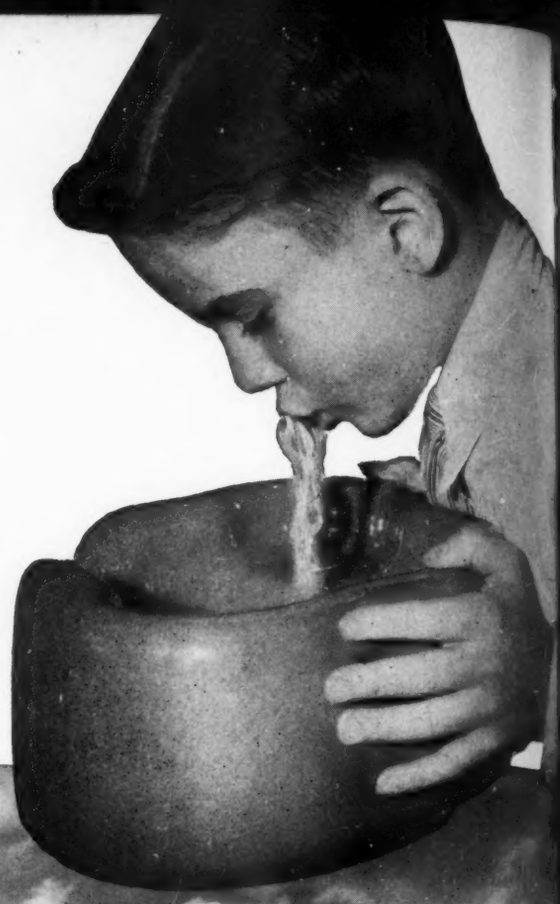
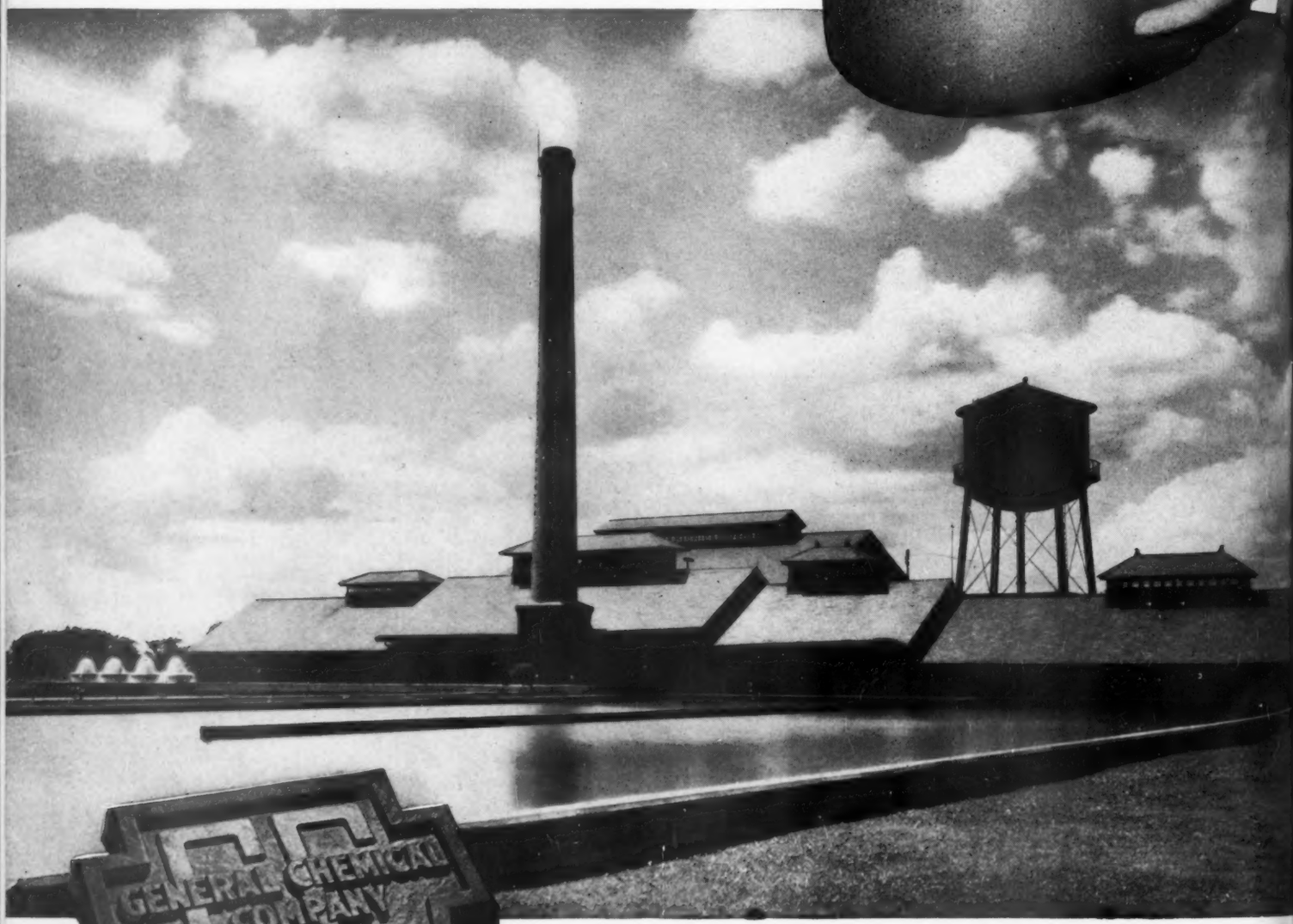
Sodium Sulfate • Phosphoric Acid • Trisodium Phosphate
Sodium Hyposulfite • Sodium Silicate • Disodium Phosphate





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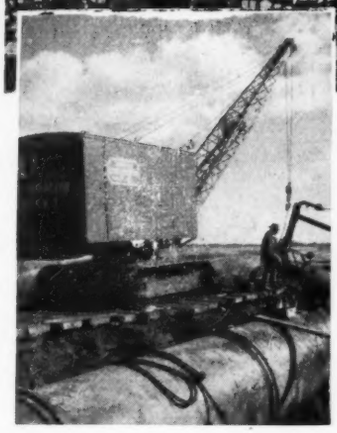

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Mr. L. Van Gilder is Engineer and Superintendent of the Water Department of Atlantic City.

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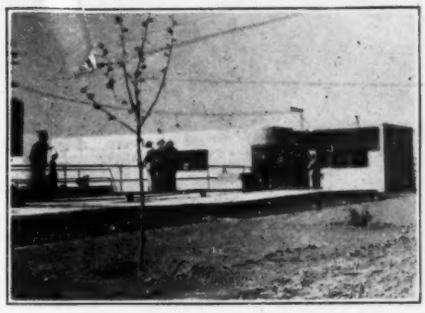
WRITE TODAY FOR LITERATURE

Eleventh Annual Spring Conference

CALIFORNIA SEWAGE WORKS ASSOCIATION



Visalia Had Its New Plant to Show.

By A. M. RAWN*
Associate Editor, Water Works & Sewerage

AMONG the early American settlements in California, Visalia, host to the California Sewage Works Association on April 14 and 15, takes prominent position. Settled in 1852 during the great migration to the Pacific slope, it lies close to the foothill pastures of the Sierras; is surrounded by the rich Central Valley agricultural lands and serves as gateway to two of the State's most impressive big-tree parks—Grant and Sequoia. It reflects its early days in the type and character of the older buildings as well as the wealth of foliage which lines its avenues. In April the acacias, locusts, conifers and iris are at their best. The city's hospitality, as might be expected from its history and traditions, partakes of the flavor of its pioneer years.

If one is interested in astronomical figures, he may ponder the fact that in the Sierras lying east of the city, are a million ancient redwoods — more than 12,000 of which are over a century old, and many of these towering forest giants were seedlings before the birth of Christ. The oldest among them were flourishing young trees while the pyramids of Egypt were being constructed. Contrast with this the fact that for years the City of Visalia owned the smallest public park to be found—San Juan Park—a single large oak, preserved in the center of one of the city streets and enclosed by a stone fence!

We Unwrap a Brand New Plant

Of interest, more practical than esthetic, to those in attendance at the Conference was the fact that Visalia was boasting a brand-new sewage treatment works with which to greet the members, and made the occasion of the meeting something of a "kick off" in respect to starting it into operation. Added to Mayor J. Pierce Gannon's warm welcome to Association members, removal of the cellophane wrappings from a new plant made the occasion an auspicious one.

As usual work commenced at 7:00 a.m. (California Time) the first day, April 14, with a Directors' Breakfast, carried on through a business session until ten o'clock; thence to a description of plants to be visited the next day. At luncheon Mayor Gannon extended a word of welcome—spoke of the educational campaign preceding construction of the city's new sewerage facilities and congratulated the Association upon the impetus it has given sanitation in California. Professor Leon B. Reynolds of Stanford University amused the group by reading a parody upon what he described as "The Last Will and Testament of Alexander (the Great) Bell," President of C.S.W.A. for 1939.

San Franciscans

D. A. Wilder, Director of Public Service and President of the Association, Alexander Bell, W. & T.'s Pacific Coast Manager.

Technical sessions in the afternoon included a discussion of occupational hazards to sanitary employees, a review of Hodgson's "Sewage and Trade Wastes Treatment"; concluding with a symposium on advanced methods in sewer pipe construction by representatives of the manufacturers.

Something Not Found in Sewage

Friday's evening banquet was the occasion of an event which will live long in the memories of those who attended. F. T. Litchfield, vice-president of the Wells-Fargo Bank and a consulting engineer, scheduled to speak upon the prosaic subject, "Observations of Testing Laboratories of Europe," deftly wove into his discussion a sermon upon Americanism which had his auditors sitting on the edges of their chairs. Mr. Litchfield recounted how, as a member of an American Commission, instructed to learn what was new in the laboratories of Europe, he and his companions moved through England, France and Germany observing things scientific, economic and political, and came away more than ever confirmed in their belief in America and this country's close kinship with England. In a manner combining the dispassionate judgment of the engineer and banker, with a chauvinism which he frankly admitted, the speaker left his listeners relieved to land again on American soil after wandering vicariously about strife-torn Europe for an hour or so.

The Conference adjourned the following afternoon at Bakersfield after visiting the sewage treatment works at Visalia, Delano, Wasco, Crawford and Bakersfield. The annual meeting will be held in September, 1939, in Oakland.

Descriptions of Sewage Treatment Plants Inspected

(See tabulated data)

"Visalia," by N. A. Huth, City Engineer.

Mr. Huth stated that final effluent from this plant (1.6 mgd.) is disposed of upon 160 acres of adjacent farm land. Like many cities, Visalia

*Assistant Chief Engineer, Los Angeles County Sanitation Districts.

Plants—California's Newest.

(1) Wasco's Clarifier, showing the Currie Surface Air Sweep. Note adjustable air-jet nozzles around periphery of tank. Floating matters are swept to center. (2) With front rank precision Visalia's battery of trickling filter nozzles swings past, as if in proud review. (3) Visalia's air scum-jet headers are located at intervals across the tank. In the center is the air-blower supplying the effective scum-jets; beside it Frank S. Currie, inventive San Bernardino engineer.

has grown out to its plant and it cannot be hoped that the irrigation feature without further treatment of effluent will long continue. A feature of the new plant, as well as the Delano Plant, is the Currie air-jet skimming arrangement. At Visalia the subsidence tank is rectangular. Cross tank air laterals, with adjustable jets, are located at intervals just above the liquor surface. Air fans out from the jets and gently blows floating material to a tilting skim-trough at the influent end.

"Delano," by Glen Johnson, Service Manager.

The original works for Delano were built in 1922. Rapid growth of the city rendered the first works, including an Imhoff tank, inadequate some years ago. P.W.A. money was the incentive which prompted construction of the new (1939) plant. Water used in home air conditioning plants influence hourly sewage rates to the extent that peak flows reach Delano's distant plant between one and three in the morning. The city leases the sewer farm to a tenant at $500 annual rental and gives him the sewage effluent. Care in application of sewage to the soil has resulted in increasing the fertility of formerly waste land so that in more than 50% of the spreading area two good crops are produced annually—barley and milo-maize. Excellent plant isolation will probably permit the continued economical practice of irrigation without further treatment of effluent.

"Wasco," by Tipton Matthews, Sewage Plant Operator.

Mr. Matthews described how Wasco had proceeded under a bond issue of $90,000 and a P.W.A. grant of $61,000 to construct sewers and a (1937) plant. Sprinkling filter effluent (chlorinated) is used as irrigation water on adjacent farm lands. Wasco is the center of one of the most extensive potato raising areas in the county and fourteen potato washing establishments are tributary to the treatment plant. When all are in operation, the flow of wash-water exceeds 450 gpm. of muddy water containing large quantities of potato skins. So far the plant has stood the jolt. The circular settling tank at Wasco is also equipped with skimming air jets around the periphery which move scum to the tank center for skimming.

"Bakersfield," by J. L. Holfelder, City Engineer.

The present work at Bakersfield comprises a revamping of portions of the collecting system and construction of a new plant. Three small pumping stations are abandoned at the cost of an interceptor and one central station. The new works are designed for chemical precipitation. A design innovation is the combination flocculator—clarifier. Designed as a circular tank, the flocculation chamber is surrounded by an annular ring to provide the clarifying section. Sewage enters at a central pedestal, is dosed and mixed, and flows radially through the annular subsidence ring to the peripheral weir. Digester walls are being designed as prestressed reinforced concrete rings. Chlorinated effluent is used in a section or two of adjacent pasture land.

"Tehachapi," by C. S. Chetwood, Water Superintendent.

This plant, located at elevation 4000, is subjected annually to severe freezing temperatures. (Disturbing to California low-landers — Ed.) Despite this, the operator reports no difficulties from sludge digestion or effluent disposal; the latter via ponds or lagoons and subsequent percolation to Tehachapi Creek, from which it is later diverted for irrigation.

Papers and Discussion

"Occupational Health Hazards in Sewage Disjosal Plants," by Dr. John P. Russell, Chief, Bureau of Industrial Hygiene, California State Department of Health.

Dr. Russell first enumerated the characteristics of various gases encountered in sewers and sewage treatment plants. He stated that of the gases CO and CO_2 might be classified as suffocating; CH_4, H_2S, and hydrocarbon vapors are explosive. Ammonia and hydrogen sulphide are toxic. Maximum safe concentrations of H_2S in the atmosphere are less than 50 p.p.m.; and 0.1% may cause death from paralysis in a few minutes. Ammonia in concentrations of 100 p.p.m. is safe; but 0.25% will cause dangerous illness within an hour.

Some of the Ladies

(1) Mr. and Mrs. Winston Updegraff of Los Angeles (Mr. U. is Los Angeles Manager of "Western City"). (2) Mr. and Mrs. Jack Kimball of Palo Alto (Mr. K. is a member of the City Engineer's Staff). (3) Mr. and Mrs. J. F. Smith of San Francisco (Mr. S. is Great Western's Manager of Sales).

Activities.

(1) We lunch at the Elk's Club with Mayor Gannon and City Manager Philippe. Down the table we see Col. H. G. Smith (Los Angeles); Mr. Philippe and President Bell and the Mayor. (2) L. to R.—Reinke, Gray, Bell, Bowen, Gillespie. (3) L. to R.—J. H. VanNorman, Carl Beyer, W. T. Knowlton, Robert Mayer, H. H. White. (4) Directors at Breakfast—Around the table from the left are—Phelps, Kennedy, Smith, Bell, Tennant, J. Smith, Gray and Rawn.

Gasoline vapors frequently found in sewers are not only explosive but are poisonous. Surprising to many, as little as one-tenth of 1% is toxic and gives the indication of drunkenness; 2% will cause death in one hour. CO_2 is asphyxiating, 2% to 3% being the maximum tolerance, higher concentrations causing suffocation. CO is asphyxiating and while not considered a true poison, robs oxygen from the tissues; one hundredth of one percent in the atmosphere will cause headache and mental confusion; higher concentrations result in loss of consciousness. Less than 16% of oxygen in the atmosphere is hazardous and less than 10% results in suffocation. CH_4 (methane gas) is explosive in concentrations of 5% to 16% in ordinary air. It is lighter than air and tends to lie along the sewer crown.

Dr. Russell discussed the exposure of sewage workers to diseases, waterborne and otherwise, and stated that of these dysentery, typhoid and jaundice are most common. Prevention against dysentery is cleanliness; against typhoid, vaccination, which is to some extent effective against jaundice also. He described the latter disease as one contracted from the urine of rats and may be taken through abrasions in the skin and through the mouth.

The paper provoked spirited discussion. A number of possibilities which he had not touched upon were developed; to-wit: certain combinations of gases and lack of oxygen in the atmosphere might result in trouble, even though the safe limit of either had not been reached. Two cases of gonorrheal infection of the eye, contracted from splashing raw sludge, were described. Death in the El Centro sewer of two inspecting engineers was discussed with some speculation as to whether H_2S or CO_2 was the responsible gas.

"Sewage and Trade Wastes Treatment," the text by H. J. N. Hodgson of Australia, was receivel by Professor C. G. Hyde: As a preface to reading extensively from Mr. Hodgson's conclusions, Mr. Hyde stated that he considered Hodgson's comments on his observations in Holland, Germany, England and America, one of the greatest single contributions to the sanitary field since the late Rudolf Herring's report on German practice published in the 1880's. Professor Hyde's remaining remarks consisted of reading paragraphs of outstanding interest from Mr. Hodgson's book.

[Mr. Hodgson, a Sanitary Engineer serving the Federal Government of Australia, spent a year or longer in the United States about two years ago making a study of American sewage practices. Almost another year was devoted to the same procedure in Holland, Germany and England. During this study term he gathered much of the material published in his recent book so well thought of by Professor Hyde.—Ed.]

Advances in Sewer Pipe Manufacture

(A Symposium)

"Transite Pipe," by Mr. J. H. Peterson, Staff Manager, Transite Pipe Department, Johns-Manville Corporation.

Mr. Peterson described "Transite" pipe as composed of Portland cement and asbestos fibre molded under pressure. Twenty-two factories now supply "Transite" pipe for use in a thousand cities.

Mr. Peterson proposed "Transite" pipe for use in sewers because it might be moulded in long sections; because of its low friction represented in Cutter's formulae by values of "C" from .009 to .011; and also because of the readiness with which lateral lines may be cut-in at any point. He concluded his remarks by describing the flexible joint consisting of a "Transite" collar, resting on rubber annular rings in the annular space between the collar and each section of the pipe; and advanced the thought that flexibility might be a virtue in a land of frequent siesmic disturbances.

"Asbestos Bonded Corrugated Pipe"—by L. W. Wyman, Chief Engineer, California Corrugated Culvert Company.

Recounting the history of this construction, Mr. Wyman stated that the corrugated principle was invented in 1896; that by 1906 the merit of the additional strength resulting from the corrugations was

From Near and Far

(1) Visalia's City Engr.—N. A. Huth; (2) From P. W. A. Travelling Engr. P. V. Cooper and Regional Engr. W. L. Felt. (3) A. L. Genter, Chemical Engr. of Baltimore (Daddy of Sludge Elutriation). (4) W. A. Ingraham (Stockton) and J. H. VanNorman (Los Angeles). (5) Mayor and Manager of Visalia—J. P. Gannon and J. J. Philippe. (6) J. C. Clark. Chief Operator from Huntington Beach.

commonly accepted, and by 1920 this type of structure had been accepted as standard for highway culverts. As a result of investigations conducted in 1925-26, his company concluded: first, that the flexible feature of the pipe structure rendered it less liable to failure under excessive load than any other character of pipe. Second, that failures had been due to corrosive and abrasive action of water in the invert, with some traces in the crown. At about this time they decided to render the invert less susceptible to attack by paving the invert with an asbestos reinforced tar pad, vulcanized into position, and to paint the entire inside of the pipe with acid-resistant tar to preclude corrosion. Mr. Wyman stated that an examination of 20,000 feet of separate domestic and storm sewer, 6 to 12 years of age, indicated that the methods of protection were quite successful.

"Unglazed Clay Pipe"—by Mr. H. W. Jewell, Engineer, Pacific Clay Products, Los Angeles.

Mr. Jewell told how his firm and local associates had blended a high-strength clay which matured at temperatures well beyond the salt glazed product; how the density of the clay body had been greatly increased and the impermeability of the pipe improved by extruding the clay under vacuum. He said that by treating the surface of such clays prior to firing, a truly smooth impervious glaze was being applied. The Los Angeles clay manufacturers, he stated, have in recent years contributed to the art of sewerage high-strength, impervious clay pipe and special acid-resistant, rootproof joints. They are now manufacturing clay pipe in sizes up to 42 inches in diameter, 6-foot length, equipped with reinforced concrete collars for joining, and of strength required to resist the external pressures imposed by a trench depth of 20 feet. Mr. Jewell stressed the need for impervious pipe walls, stating that many lines built with water-and-root-proof joints, but seeping walls, failed because roots reaching for moisture around the pipe, finally moved it slightly, displacing a joint. Through the ruptured joint these same roots found their way and clogged up the otherwise well-built structure.

"'Amercoat' Concrete Pipe"—by Ernest F. Bent, Vice-President, American Concrete and Steel Pipe Company.

Mr. Bent stated that for men interested in sewer construction, he had a word of hope that his firm was well along the trail leading to a solution of the problem of internal protection for concrete sewer pipe. He described "Amercoat" as a synthetic resin which, when applied to a concrete surface, protected it from attack by acids and alkalis. Laboratory experiments having proven it resistant to all destructive agencies ordinarily found in sewage and sewers, it was now undergoing long-time tests in the sewers themselves. To date the coating has, in most instances, been entirely satisfactory although certain minor changes in composition may be made to extend the field of application and insure more satisfactory results in exceptional cases. Mr. Bent reviewed the history of concrete pipe difficulties in the southwest and traced the development of protective linings in which his firm has played so important a part. Each investigation, he stated, leads closer to a solution of the problem, and he now looks confidently to the synthetic plastics to provide the final answer.

FACTUAL DATA ON CALIFORNIA PLANTS DISCUSSED AND VISITED

	Visalia	Delano	Wasco	Bakersfield	Tehachapi
Present population	10,000	4,000	3,800	40,000	1,000
Present flow—M.G.D.	1.6	0.314		4.0	
Design population equivalent	20,000	8,000	6,000	45,000	2,500
Design flow	3.12		0.60	7.0	0.15
Primary treatment	Sedimentation	Sedimentation	Sedimentation	Chem. Coagulation & Sedimentation	Imhoff
Secondary treatment	Spr. Filters	None	Spr. Filters	None	Spr. Filters
Final treatment	None	None	Chlorinated	Chlorination	Ponding
Effluent disposal	Irrigation	Irrigation	Irrigation	Irrigation	To creek
Sludge treatment	Digestion	2-stage digestion	2-stage digestion	2-stage digestion	Imhoff
Sludge disposal			Fertilizer		Imhoff

*The plant of Tehachapi was described but not visited.

OHIO SECTION HOLDS FIRST MEETING

The new Ohio Section of A.W.W.A. less than a year "young" held its first annual meeting in Dayton, the home-town of its first A.W.W.A. Director, Wallace W. Moorehouse. The registration was something over 130; the technical program proved to be of usual Ohio standards, and entertainment of a high order.

Indicative of the growth of the new section an aggressive membership committee, headed by Hayes R. Kuhns, has in a few months boosted members from 98, when the Section was formed, to better than 150 at the close of the first meeting.

The following were elected officers:

Chairman — W. C. Lawrence, Cleveland.

Vice-Chairman—M. F. Hoffman, Cincinnati.

Secretary-Treasurer—T. R. Lathrop, Columbus.

A.W.W.A. Director—W. R. LaDue, Akron.

Trustees—C. E Inman (Warren) and F. P. Fischer (Cleveland).

The Geo. W. Fuller Award was voted to W. R. LaDue and W. C. Lawrence, jointly, in recognition of their enterprise in promoting the Ohio Section, and energies devoted to it since.

Akron was chosen as the 1940 meeting place.

We regret that it has proved impossible to meet our prior obligations, in respect to material scheduled for this special issue, and also to print the report covering the highly successful First Annual Meeting of the new Ohio Section of A.W.W.A. this month.—ED.

HIGHLIGHTS OF CENTRAL WEST WATER WORKS MEETINGS

As Reported By

H. E. HUDSON, JR.*
CHICAGO, ILL.

A W. W. A.'s two midwestern sections devoted themselves to programs of broad variety during their late April meetings. The Illinois Section held its thirty-first annual meeting April 20-22, at Champaign, Ill., and the Indiana Section convened for the thirty-second time April 25-26 at Indianapolis. Registrations at Indianapolis reached a new high at 228. Although no record was established, the Illinois Section attendance was likewise excellent.

The Geo. W. Fuller awards by the two Sections were presented to John R. Baylis, Physical Chemist, Chicago, Ill., (Associate Editor of WATER WORKS AND SEWERAGE) and to H. A. Dill, Water Company manager, Richmond, Ind. The award to Mr. Baylis was made "for his outstanding contributions to the theory and practice of water treatment over a period of years." Mr. Dill, A.W.W.A. Director, representing the Indiana Section, has long and well served the water works profession, and was cited for such services and his valued mature judgment in association matters.

Entertainment Unusual

After the introduction of guests and National officers of A.W.W.A., the Hoosiers were entertained by Prof. THURMAN B. RICE of Indiana University, who turned his hobby into fun for the evening. His talk on stamp collecting, "Fun in Filately," was rich with anecdotes about various stamp issues. At Urbana, the water-workers were treated to a vaudeville show by the University of Illinois Gymkana troupe, which presented a variety of acrobatic and musical novelties. On the evening of the 20th, the spectacular sound film "Steel—Man's Servant" was presented for the Illinois Section.

*The author, Junior Sanitary Engr. in Chicago's Dept. of Public Works, has just been elected Secy.-Treas. of the Illinois Section of A.W.W.A.—Ed.

(L.) Geo. B. Prindle, Supt. Highland Park, Ill. (Vice-Chairman)

(R) John R. Baylis Chicago (To Him the Fuller Award)

Section Affairs

Illinois

Highlights of the Illinois Business Section was the adoption of a resolution "to invite the National A.W.W.A. 1940 convention to meet at Chicago." New officers of the Illinois Section are:

Fred G. Gordon, Chicago, Chairman.

Geo. B. Prindle, Highland Park, Vice-Chairman.

H. E. Hudson, Jr., Chicago, Secretary-Treasurer.

F. W. Hartman, Chicago, Trustee.

H. H. Gerstein, Chicago, Trustee.

Frank C. Amsbary, Champaign, Section Director.

The Illinois Section took no action on licensing operators, since voluntary certification is already in effect through the agency of an operators association.

Elected to serve the Indiana Section during the next year were:

M. H. Schwartz, Vincennes, Chairman.

*J. H. Bruhn, Indianapolis, Vice-Chairman.

Herman Horstman, Indianapolis, Secretary-Treasurer.

H. J. Draves, Michigan City, Assistant Secretary.

**Howard A. Dill, Richmond, A.W.W.A. Director.

*For the past several years, Secretary-Treasurer.

**Elected in 1938.

Indiana

Outstanding activity of the Indiana Section has been its promotion of water works short schools during the past four years. C. D. ADAMS, Indiana Public Service Co., New Albany, reviewed the note-worthy progress of these schools, and their value. Impressive was the fact that last year 98 supplies—nearly one-third of all in the State—were represented at the schools. In Indiana, a bill for licensing water works and sewerage plant operators was sidetracked in the legislature, due to lack of operator support. So reported Prof. R. B. WILEY, of Purdue University, for the Licensing Committee. While the proposed law may not have satisfied all operators perfectly, he felt it had deserved their support. Prof. Wiley added some information on a water works short school to be held at Purdue, sponsorship having come from the Social Security Administration.

Illinois Technical Sessions

The development of ground water from gravel packed wells was discussed by Mr. A. W. MCLEAN, Layne-Western Co., Chicago, who explained various methods of building high capacity wells by the use of gravel packs. Mr. E. W. BENNESON, Edward A. Johnson, Inc., St. Paul, told of the construction and use of corrosion resistant metallic well screens. After pointing out desirable qualities in screens he summarized recent trends in screen use. Screens were once chosen to hold out fine sand, but present practice makes the openings such as to exclude the coarsest 50 to 90 per cent of the water bearing material only—the fine sand being removed by development pumping.

Exhibiting several representative specimens, Mr. Benneson revealed the effects of corrosion on various

screen materials. His presentation was followed by a movie showing methods of well construction in Canada, Argentina, France, Tunisia, and Indo-China.

A panel discussion on "Ground-Water Improvement" was led by C. W. Klassen, State Sanitary Engineer, who made a brief statement on the need for improvement of ground

(L) F. W. Hartman, Chicago (National Meter Co.)

(R) H. H. Gerstein, Chicago (Purif. Div., Dept. Public Wks.)

waters. In addition to economic reasons, said Mr. Klassen, ground waters frequently need improvement in palatability to prevent consumers being driven to use unsafe supplies, and to increase the number of private supply cross-connections on public supply systems. Hard waters lead to the use of home softeners which introduce contamination in some cases. Supplies containing iron had proved unsalable in one or two instances in Illinois, making the public water supply economically unsound. Mr. Klassen pointed out that while almost all Illinois communities have pubic supplies, there is still ample need for improved treatment of these supplies—more to render them pleasing to drink and economical to use in home and industry, than safe to consume.

Treatment of Ground Waters

Decided ground water improvement was shown graphically through softening processes by Dr. GORE, Illinois State Water Survey, Urbana. Hardness and alkalinity can be reduced 50% in many cases. A. S. BEHRMAN, International Filter Co., Chicago, described the newer softening processes exemplified by the "Infilco Accelator" developed and successfully marketed by his company. Six such installations have been made on Illinois supplies, some of which he described. He also presented some operating data on these plants, which in many respects follow a similar principle to that of the Spaulding Precipitator.

Zeolite treatment was discussed by WM. H. MITCHELL, Permutit Co., Chicago. He told how much can be expected of zeolite plants and laid considerable emphasis on the newer carbonaceous hydrogen zeolites. These are used for softening, for sodium bicarbonate removal, and for iron removal. They are regenerated with acid.

Methods of measuring hardness were analyzed in a paper by C. R. KNOWLES, Illinois Central System, Chicago. This paper pointed out some of the practical disadvantages of the soap test: inaccuracy, poor magnesia readings, and commonly low readings. The I. C. R. R. has been using the palmitate test with good results and an appreciable saving of effort.

Pipes—Main Sterilization—Corrosion

Choice of pipe wall thickness based upon trench loads and working conditions was the theme of M. L. ENGER, Dean, College of Engineering, University of Illinois. He proposed a method for choosing pipe on the basis of actual service conditions as a rational design measure. Another contribution from the University of Illinois was an explanation by PROF. J. J. DOLAND of the Cross method of successive approximations for calculating flow networks in distribution systems. This method, recommended for its relative simplicity, has been used in a number of cities with reliable results.

[Those interested should secure Engineering Bul. No. 286 from the University of Illinois.—ED.]

Difficulties with sterilizing water mains have caused Springfield, Ill., endless worry, according to S. T. ANDERSON of the Springfield Water Department. Various methods of disinfecting new piping have been tried with little success. Method promising best results is the liberal use of lime in the mains and mixed with the caulking material. In discussing this paper, FRANK C. AMSBARY, Supt. Illinois Water Service Co., Champaign, said he felt that lime would not prove satisfactory in all cities. At the same time, he cautioned against the use of excessive chlorine dosages for main sterilization, fearing corrosion as the consequence.

Bacteria, Corrosion, and Red Water was the subject of DR. T. E. LARSEN, State Water Survey, Urbana. In studying corrosion of the University water system, he found that the water, although fairly stable as it left the treatment plant, changed as it proceeded along the distribution system. Presence of ammonia in the water seemed to feed the iron-fixing bacteria which in turn cause changes in the chemical nature of the water. These changes appear to cause increasing corrosion rates.

Softening and Filtration

CHARLES H. SPAULDING, Supt. of Filtration, Springfield, Ill., summar-

(L) Paul C. Lanx, Anderson, Ind. (Retiring Chairman Ind. Section, Long A Wheel Horse)

(R) Howard A. Dill, Supt., Richmond, Ind. (Director A.W.W.A. Voted The Geo. W. Fuller Award)

ized two years' operating results at the new "Precipitator" plant. It has been economical to operate, has produced non-corrosive water, and has put out a bacterially satisfactory effluent. Cost of operation is $14.84 per M.G. compared to $19.50 at the old plant. F. L. COVENTRY (Mattoon) described some experiments which he had been carrying on in water softening. He has found the use of sodium hexa-meta-phosphate a satisfactory substitute for recarbonation.

The Morse (All-Steel) Filter Plant was described in detail by EDWARD E. ALT, Chicago Bridge and Iron Co., who pointed out the advantages of the all-steel structure. Chief advantage claimed is a saving of 25 to 40 per cent in construction. RICHARD WILLIAMS, a colleague of Mr. Alt's, added some details on design, operation and construction of the several Morse plants already in service at various points.

Chicago's Filter Plant

Chicago's South District Filtration Project" was the topic covered by LORAN D. GAYTON, City Engineer of Chicago. After telling some of the historical background of water treatment at Chicago, Mr. Gayton outlined the essential design quantities being used in the present planning work. The new plant is to serve three South side pumping stations and have a maximum capacity

of 450 M.G.D. Features a little out of the ordinary are design for a maximum filtration rate of 4 gpm. per sq. ft., and a minimum settling time of two hours. The plant will be equipped to feed alum, copperas, chlorine, ferric sulfate, sodium silicate, sulfuric acid, lime, activated carbon, and ammonia. Some unusual problems faced the designers at Chicago in planning the preliminary construction of the breakwater, intake, and retaining wall. Among these are a fluctuating lake level, sand accumulation along the shore, and outcropping rock at the plant site.

(L) H. J. Draves, Supt. Michigan City, Ind. (Elected Asst. Secy.-Treas.)
(R) John H. Bruhn, Indianapolis Meter Co., Retiring Secy.-Elected Vice-Chairman

The concluding technical session at the Illinois meeting was devoted to swimming pool maintenance and sanitation. The two authorities on this subject were H. L. WHITE, University of Illinois, Urbana, and CHAUNCY HYATT, State Department of Health, Springfield. Both emphasized that a very large part of the load imposed on swimming pool treatment equipment is brought into the pools by individuals who fail to use the two "S's"—Showers and Soap. He suggested that pools need good rules and operation more than they need better equipment.

Indiana Technical Sessions

Chairman, Paul C. Laux, Presiding.

"Water works improvements at Evansville," were recounted by LOUIS A. GEUPEL, Supt. of Water, Evansville. With the aid of a motion picture, he showed 1937 flood conditions and the progress of recent construction which will protect the Evansville water plant against future floods of greater magnitude than the last great one. Some increases in plant capacity have been made, too.

REEVES NEWSOM, A.W.W.A. President, commented on current water works problems. He told of developments in standardizing plumbing fixtures. He also brought up the problem of charges for automatic

"Spark Plugs"
Indiana - Illinois
(L) John Ford, Past President, Indiana Section
(No. 1 A. W. W. A. New Member Getter in Central West)
(R) Frank Amsbary, Supt., Champaign, Illinois
Elected A.W.W.A. Director by Ill. Section

sprinkler service. Insurance interests are attempting to get the sprinkler charge eliminated and Mr. Newsom indicated this would be very unfair to the water industry, particularly because automatic sprinklers require that the system be designed to meet the excessive load when it comes.

Techniques in the use of water for fire fighting were described by CLARENCE A. GOLDSMITH, National Board of Fire Underwriters, Chicago. Two basic methods for fighting fires are (1) to cool them and (2) to exclude air. For effective work, automatic sprinklers are very useful. It is fairly common practice to paint fire hydrants to indicate the fire flow which they will deliver. Mr. Goldsmith added many details of developments in fire fighting, some of which water works men must consider in the design and operation of water systems. F. C. JORDAN, Indianapolis Water Co., commented on the need for firemen to be familiar with the water system in order to know how much water is available at any location.

A splendid film on customer relations was exhibited by the Indianapolis Power Co. It showed the need for pleasant personal contacts and emphasized four main points in obtaining them: (a) Interest in the customer, (b) Courtesy, (c) Personal appearance, and (d) Friendly attitude, and look it.

Metering Practice

Meter setting and controlled compounding of meters was the subject covered by L. S. VANCE, Chief Engineer, Water Department, Louisville, Ky. At Louisville installations of battery meters utilizing angle check-valves have been developed and they have greatly increased revenue in some cases due to predominantly low flows. Such installations of meters in parallel also make possible meter removal without interruption of flow. Mr. NIEMEYER, Meter Department Head, Indianapolis Water Co., added some of his experiences with meter compounding and emphasized consideration of the all important matter of loss of income due to installations of oversized meters, regardless of types. His slogan, in effect,—"Oversize Your Service Pipe and Undersize Your Water Meter."

HARRY E. JORDAN, A.W.W.A. Secretary, gave the Section a splendid discussion of factors underlying water works efficiency. Most important of these is the insecurity of many water works men, who are subject to dismissal when political turnovers take place. Mr. Jordan emphasized the need for good business management of public as well as private water utilities, suggesting that the Commission type of management has the best record for public supplies. Water works men should build themselves up in their communities, he said. They ought to cooperate with other community organizations in order to make known the value of their services.

Pipe-Line Materials

A bold analysis of the "Relative Values of Pipes of Various Mate-

A "Shot in the Dark" at Indianapolis
(Mr. Hudson captioned it "Visual Education")

rials," was made by L. R. HOWSON, Consulting Engineer, Chicago. After assuming the life, maintainance cost, installation cost, and other factors, he calculated comparable expenses of using various materials, including cast iron, steel, thin steel, and transite pipe. While the differentials were not great for the sizes he considered (up to 24-inch) other factors deserve consideration. Most important of these is strength. Pipe claimed Mr. Howson, should be purchased on the basis of expected longevity and stamina—as measured in terms of resistance of the material to physical forces. Water supply mains to have adequate safety factors, should be compared on the basis of strength per dollar. Employing the Fairchild formula, wide differences between the various materials discussed were shown by such calculations — likewise, the part played by protective coatings in purchasing sustained capacity along with strength.

Trends in Treatment

During the past decade, said H. E. HUDSON, JR., Chicago, water works men have advanced their knowledge in every phase of water treatment. These advances were stimulated by economic and social forces and came about largely through increased collaboration in the technical societies. Mr. Hudson briefly discussed the many changes in theory and practice of water treatment. The filter cannot operate well unaided, he claimed, and realization of this has brought some remarkable improvements in the preliminary processes of raw water preparation.

J. C. VAUGHN, Superintendent of Filtration, Hammond, Ind., added some experiences to Mr. Hudson's presentation. He reported excellent results from the use of "Ferrisul" as a coagulant, claiming present coagulation costs of less than 80c per million. Gross contamination of Hammond's raw water, due to reduced diversion through the Chicago Drainage Canal, has created serious problems in operating his plant. Hammond has been able to meet these through heavy pre-chloramination. LEWIS I. BIRDSALL, General Chemical Co., Chicago, commenting briefly, emphasized that more careful control of water quality is of growing importance.

C. K. CALVERT, Filtration Engineer, Indianapolis Water Co., presented a very comprehensive paper describing Indianapolis' new "Floctrol" mixing-coagulating equipment; experiments in cupric-chloramination; tests on chlorine absorption as effected in degree by increasing dosages, revealing therein an oxidation zone; increased standards for water quality; water main sterilization studies, showing the shortcomings of the practice due to organism growth originating in joint caulking materials and not effectively sterilized in a permanent manner. Mr. Calvert felt that the standards proposed by J. R. Baylis in a recent issue of WATER WORKS AND SEWERAGE would be impossible to meet, due to the presence of chlorine-resistant bacteria in most waters of the Ohio River basin. He indicated that the new mixing equipment at Indianapolis has paid for itself in two years through savings in coagulant and filter wash water. Best method found for preventing bacterial growths in caulking materials would appear to be the use of rubber such as represented in the new scheme employing rubber tubing, developed by Hayes R. Kuhns. Lantern slides of this interesting sanitary method of packing poured joints were shown by Mr. Calvert.*

L. H. ENSLOW, WATER WORKS AND SEWERAGE, New York, rose to compliment Mr. Calvert on his "four-papers-in-one." [To this—your correspondent adds "Amen."]

*NOTE: Elsewhere in this issue appears an article by Mr. Calvert comprising parts of his "four-papers-in-one." In it the Kuhn's joint packing method is described.—Ed.

NEW USE FOR CHEMICAL FEEDER AT ARMOUR INSTITUTE

Professor Vagtborg & Friend

At Armour Institute of Technology in Chicago, Prof. Vagtborg has his Sanitary Engineering students operating an experimental softening and filter plant. To produce synthetic "problem waters" of varying quantities, the professor wished to inject solutions of different composition in exact proportional quantity.

This unique idea appealed to Jeff Corydon (Skipper of the Treatment Trailer, with the inevitable pipe in the picture above) who is supplying a Proportioneers' Heavy Duty Midget for the purpose.

A second machine was required to proportion treatment chemicals to the "corrupted" water, for the purpose of purging it of its sins in the experimental treatment process. Since machine No. 1939 had just turned up on the production line, as that to go out to Armour Institute, Skipper Corydon dubbed it the "World's Fair Midget," had its metal exterior parts chrome plated, and shipped it all done up in cellophane and ribbon to Professor Vagtborg. Of this unique package we have just received a very effective picture, which is reproduced in this issue on the page devoted to "News of the Manufacturers."

HOW'S YOUR METER SETTING?

By D. R. TAYLOR
Plant Superintendent
ROANOKE, VIRGINIA

"Doc." Taylor

Roanoke, Virginia,
May 2, 1939.

Dear Bill:

Do you remember back when, if your dad called you Bill, everything was "O.K."; but if he said, "Come in the house, William," you knew that he had discovered who had broken the front window pane? Those were the good old days before we had D_2O (heavy water), CO_2, and pH—back when this country needed a good 5c cigar.

In recent years concerted effort has been made to enable us to enjoy an "abundant life," although the trend now seems to be turning a little back toward "rugged individualism." Bill, what this country needs now, more than a good 5c cigar, is a good meter setting. The taxi driver said what he liked most about his work were the people he "ran into." And, here is one idea we "ran into" twenty years ago, and we haven't found anything since that would beat it.

Most meter settings consist of an iron box and a concrete or tile barrel. It is a simple matter to procure an iron box, but, Bill, the barrel is a "horse of two other colors." If you use a barrel that is large enough at the bottom to allow the meter service men to operate wrenches conveniently to remove or reset the meter, the top of the barrel is so large that, for the sake of safety, a very large and heavy iron box is required. On the other hand, if the barrel is small enough at the top to accommodate a smaller, lighter, cheaper, and safer cast iron box, the bottom of the barrel is too small for the work that has to be done in it.

I am sending along a photograph of our meter setting, and you will note that we are using a concrete barrel that seems to meet all of the requirements. The outside diameter of the top of the barrel is 16 inches. The outside diameter of the bottom of the barrel is 28 inches. The height is 18 inches, and the sides average 1⅞ inches in thickness. The iron box is of conventional design and can be obtained at any local foundry. We make the concrete barrel with our own forces.

This Style Meter Setting Seems to Fill the Bill.

How We Do It

This barrel is made as follows: The outside form or mold consists of two pieces bolted together, and the inside form consists of eight pieces with punched ears through which nails or wires can be inserted to hold them together until the barrel is "poured." After that the nails may be removed and the inside form easily removed. This barrel is made with a relatively dry mixture, consisting of one part cement and two parts coarse, sharp sand. This mixture is hand rammed (and I mean rammed), and the forms are removed immediately upon completion and set up for another pour. The bottom edge of the barrel may be slotted with the sharp end of a pick to accommodate a service of any depth, or these slots may be made by inserting wooden blocks in the forms during the process of manufacture.

We sprinkle our barrels twice a day for the first seven days before using them. In making these barrels in this manner from twelve to eighteen barrels can be made by one man per day and with only one set of forms. A somewhat stronger barrel can be made by actually pouring a wet mortar. However, in this case it will be necessary for you to have as many forms as you expect to make barrels in one day.

The Economy of It

Bill, we make these barrels for an average of 60c each, and we purchase our iron boxes locally for $1.50 each, making a total of $2.10 for the complete unit. We haven't been able to find a meter box with more advantages and fewer disadvantages, nor as cheap, as this type of box. If you are interested in using this type of setting, I believe that the Ford Meter Box Co. of Wabash, Indiana, can either furnish you with the proper forms for concrete barrels or they can tell you where to obtain such forms, which are superior to our Rosnolle type which we had to invent for ourselves.

Well, Bill, I presume I had better sign off. You know the call letters and the ownership. So here's hoping that I will hear from you soon.

Sincerely,

Tom.

INTERESTING!

Los Angeles goes the farthest for some of its water—280 miles to Boulder Dam. San Francisco's major supply comes from Hetch Hetchy reservoir 170 miles away. New York taps the Catskill watershed 150 miles to the north.

Chicago, with its supply in its front yard—Lake Michigan—uses the most water. It has the lowest rate of any large city in the country and the daily per capita consumption is 270 gallons.—*Cast Iron Pipe News.*

ATLANTIC CITY EQUIPMENT AND MATERIALS SHOW TO BE BIGGEST EVER

86 Firms to Exhibit

J. Herman Smith (In Charge of Exhibit)

WHAT seemingly establishes another all ttime A. W. W. A. Convention record is found in the number of firms which will exhibit materials and products at the Atlantic City Convention June 11th-15th.

Although without doubt there will be others to take exhibit space during the next 30 days remaining (at this writing) before the convention, already 86 firms have signed up for space.

The following list of exhibitors has just been released by J. Herman Smith, Chairman of the Exhibit Committee. He states that, aside from numbers, the equipment and materials "exhibition" will be by far the largest on record in respect to total square footage of space required. Therefore, an unprecedentedly elaborate "show" is to be anticipated as indicated from present planning of exhibitors It seems that something of a World's Fair tempo has taken hold of 1939 exhibitors

THE EXHIBITORS

(Release of May 10th, 1939)

Activated Alum Corp., Curtis Bay, Baltimore, Md.
American Cast Iron Pipe Co., Birmingham, Alabama
American City Magazine, New York City
American Rolling Mill Co., Middletown, Ohio
Art Concrete Works, Pasadena, Calif.
Atlas Mineral Products Co., Mertztown, Pa.
Badger Meter Mfg. Co., Milwaukee, Wis.
Barrett Company, New York City
Bingham & Taylor Corp., Buffalo, N.Y.
Birch Manufacturing Co., Chicago, Ill.
Brainard, F. S., & Co., Hartford, Conn.
Buffalo Meter Co., Buffalo, N. Y.
Builders Iron Foundry, Providence, R. I.
Carson Cadillac Corp., Birmingham, Ala.
Central Foundry Co., New York City
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Chicago Bridge & Iron Co., Chicago, Ill.
Cliff-Dow Chemical Co., Marquette, Mich.
Crane Company, Chicago, Ill.
Darco Corporation, New York, N. Y.
Darling Valve & Mfg. Co., Williamsport, Pa.
DeLaval Steam Turbine Co., Trenton, N. J.
Dorr Company, Inc., New York, N. Y.
Dresser Mfg. Company, Bradford, Pa.
Eddy Valve Company, Waterford, N. Y.
Electromarine Corp., Westport, Conn.
Electro - Rust - Proofing Co., Dayton, Ohio
Engineering News-Record, New York, N. Y.
Farnan Brass Works Co., Cleveland, Ohio.
Flexible Sewer Rod Equip. Co., Los Angeles, Calif.
Ford Meter Box Co., Wabash, Ind.
Foxboro Company, Foxboro, Mass.
General Paint Corp. (Hill, Hubbell & Co. Div.), Cleveland, Ohio
Hall Laboratories, Inc. (Calgon, Inc.), Pittsburgh, Pa.
Hayman, Michael & Co., Inc., Buffalo, N. Y.
Hays Mfg. Co., Erie, Pa.
Hersey Mfg. Company, South Boston, Mass.
Homelite Corp., Port Chester, N. Y.
Hydraulic Development Corp., New York, N. Y.
Industrial Chemical Sales Div. (West Va. Pulp & Paper Co.), New York, N. Y.
International Filter Co., Chicago, Ill.
Johns-Manville, New York, N. Y.
Keasbey & Mattison Co., Ambler, Pa.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Lead Industries Asso., New York, N. Y.
Leadite Company, Philadelphia, Pa.
Lead Lined Iron Pipe Co., Wakefield, Mass.
Lock Joint Pipe Company, Ampere, N. J.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
McWane Cast Iron Pipe Co., Birmingham, Ala.
Monsanto Chemical Co., Boston, Mass.
Mueller Company, Decatur, Ill.
National Meter Company, Brooklyn, N. Y.
Natl. Water Main Cleaning Co., New York City
Neptune Meter Co., Long Island City, N. Y.
Neptune Meter Corp. (Thomson Meter Corp.), Long Island City, N. Y.
Pardee Engineering Co., Long Island City, N. Y.
Phoenix Meter Corp., Prince Bay, S.I. N. Y.
Permutit Company, New York, N. Y.
Pitometer Company, New York, N. Y.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Pittsburgh Equit. Meter Co., Pittsburgh, Pa.
Pomona Pump Company, Pomona, Calif.
Proportioneers, Inc., Providence, R. I.
Public Works Magazine, New York, N. Y.
Red Hed Mfg. Company, Boston, Mass.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., Troy, N. Y.
Salomon, L. A., & Bro., New York, N. Y.
Simplex Valve & Meter Co., Philadelphia, Pa.
Smith, A. P., Mfg. Co., E. Orange, N. J.
S. Morgan Smith Co., York, Pa.
Sparling, R. W., Los Angeles, Calif.
Syntron Company, Homer City, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.
U. S. Steel Corp., Pittsburgh, Pa.
Vogt Mfg. Company, Louisville, Ky.
Wailes Dove-Hermiston Corp., New York, N. Y.
Wallace & Tiernan Co., Inc., Newark, N. J.
WaterLeak Detector Co., Columbus, Ohio
Water Works Engineering, New York, N. Y.
Water Works & Sewerage, New York, N. Y.
Wood, R. D., Company, Philadelphia, Pa.
Worthington-Gamon Meter Co., Harrison, N. J.
Youngstown Sheet & Tube Co., Youngstown, Ohio

Some of A. W. W. A.'s Sectional Officers Named in Recent Elections

Four States
*Director**
Abel Wolman
Baltimore

Chairman
C. J. Lauter
Washington

Illinois
*Director**
F. C. Amsbary, Jr.
Champaign

Secy.-Treas.
H. E. Hudson, Jr.
Chicago

Florida
Chairman
Geo. C. Catlett
Jacksonville

Secy.-Treas.
A. P. Black
Gainesville

Michigan
Chairman
Cyrus R. Bird
Detroit

Ky.-Tenn.
Chairman
H. N. Jernigan
Lexington, Ky.

Ohio
*Director**
W. R. LaDue
Akron

Chairman
W. C. Lawrence
Cleveland

California
*Director**
H. A. Van Norman
Los Angeles

New York
Chairman
Frank Henshaw
Scarsdale

* The Directors-Elect do not take office until the close of the 1939 Convention.

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ASBESTOS-CEMENT

PIPE

FOR WATER WORKS • SEWERS

AND INDUSTRIAL PLANTS

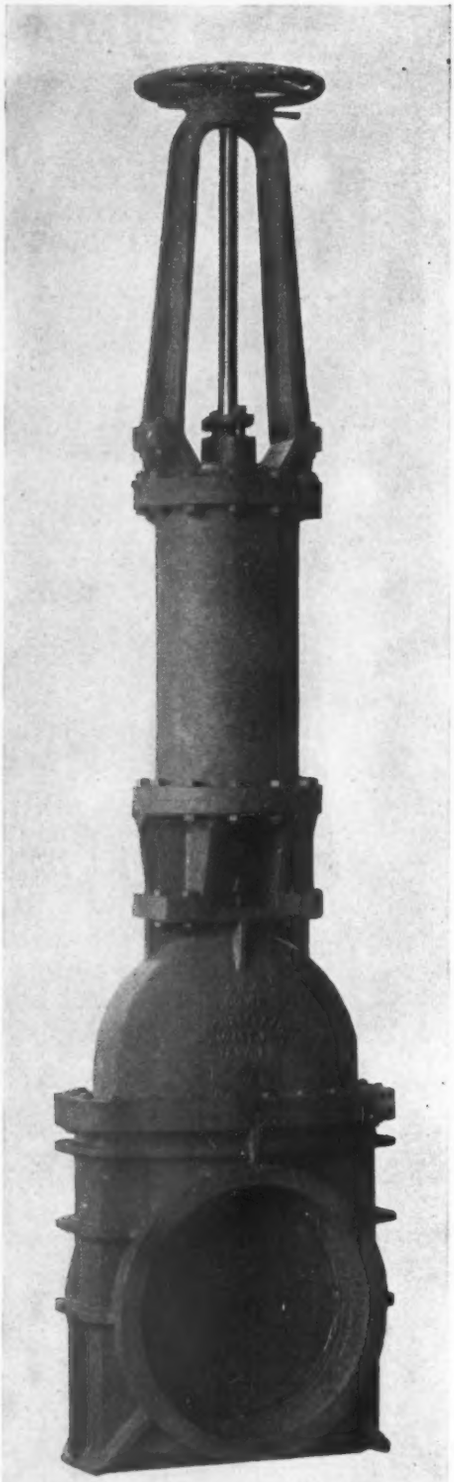
•

SEND FOR CATALOGUE

•

ASBESTOS CEMENT PIPES, INC.

225 BROADWAY NEW YORK, N. Y.



24" Rensselaer square bottom hydraulically-operated valve electrically controlled from remote point to be used by the city of Galveston, Texas, as a throttle valve.

1885-1939

54 YEARS OF ATTAINMENT

•

Continuously designing and producing RENSSELAER VALVES and COREY FIRE HYDRANTS that are—

STURDY • ACCURATE DEPENDABLE

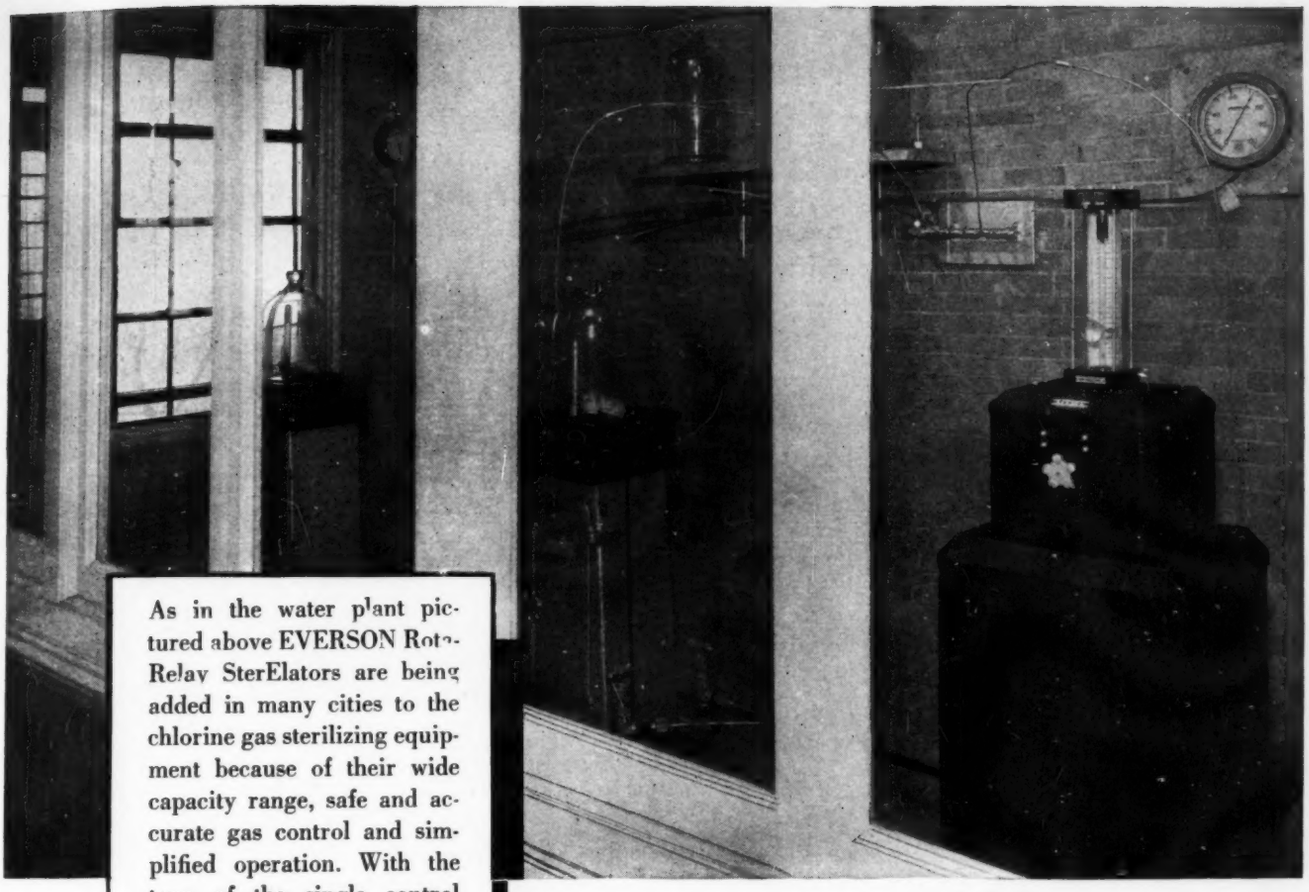
And now— in addition, designing and producing Gate Valves, Check Valves and Cone Valves to meet special problems involving Manual or Automatic Control

•

An Engineering Department is Maintained to Serve You

RENSSELAER VALVE COMPANY

TROY, NEW YORK



As in the water plant pictured above EVERSON Rota-Relay SterElators are being added in many cities to the chlorine gas sterilizing equipment because of their wide capacity range, safe and accurate gas control and simplified operation. With the turn of the single control valve, located directly below the visible meter, the model illustrated feeds chlorine gas at any desired rate from 7½ lbs. to 225 lbs. per 24 hours.

Other features include

1 Valve Control

Visible Rota Meter

Automatically Safe

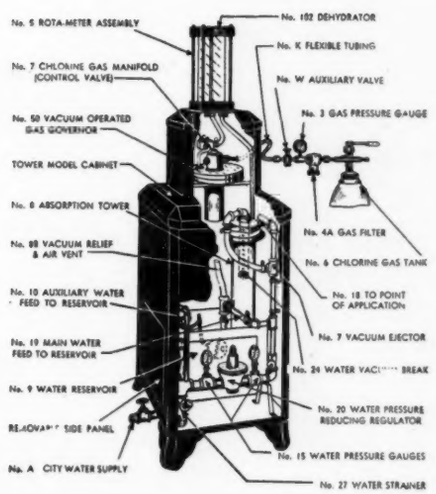
Automatic Gas Shut-Off

Automatic Synchronizing with Pump

Operates under 25″ water gauge vacuum

Multiplex Feed to 2 or more points from a single SterElator.

Everson Mfg. Co.
233 W. Huron St.
Chicago, U. S. A.

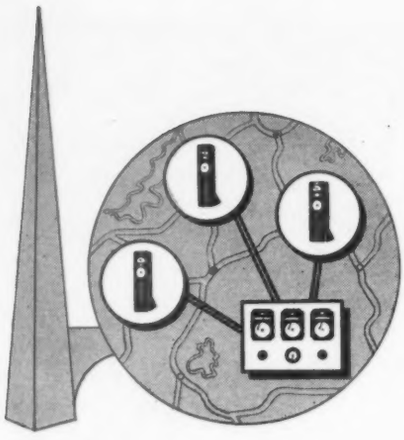

No. 5 ROTA-METER ASSEMBLY
No. 102 DEHYDRATOR
No. K FLEXIBLE TUBING
No. 7 CHLORINE GAS MANIFOLD (CONTROL VALVE)
No. W AUXILIARY VALVE
No. 50 VACUUM OPERATED GAS GOVERNOR
No. 3 GAS PRESSURE GAUGE
TOWER MODEL CABINET
No. 8 ABSORPTION TOWER
No. 4A GAS FILTER
No. 6 CHLORINE GAS TANK
No. 18 TO POINT OF APPLICATION
No. 10 AUXILIARY WATER FEED TO RESERVOIR
No. 7 VACUUM EJECTOR
No. 19 MAIN WATER FEED TO RESERVOIR
No. 9 WATER RESERVOIR
No. 20 WATER PRESSURE REDUCING REGULATOR
No. 15 WATER PRESSURE GAUGES
No. A CITY WATER SUPPLY
No. 27 WATER STRAINER

SterElators by Everson

See our advertisement on page 237 this issue

Write for Bulletin No. 1004

PROGRESS



TODAY, if Superintendent in charge of a water or sewerage system, you can sit in your office and "keep your eye on the whole works."

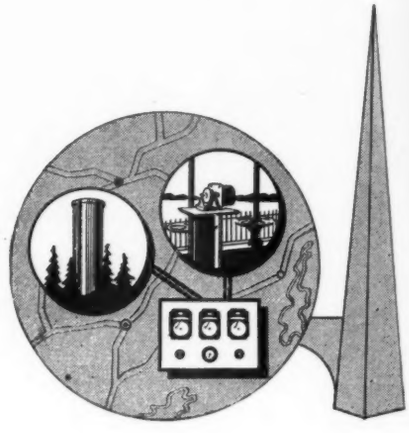
Distant Metering and Summation

You can read flow through individual distant Venturi Meters, and you can read total flow through all main lines — on Chronoflo Receiving Instrument dials centrally located.

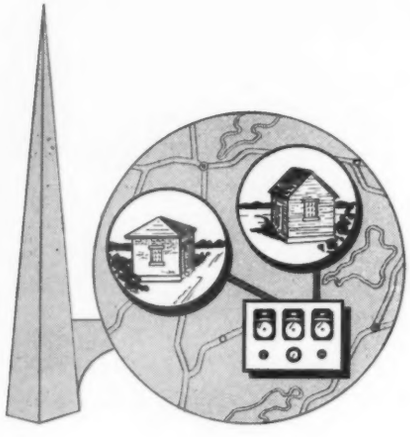
VENTURI

Outlying Reservoir and Standpipe Levels

You can read the water level in any standpipe or reservoir, no matter how far from headquarters, by glancing at the nearby Indicating and Recording Level Gauges; saves time-consuming trips or guesswork.



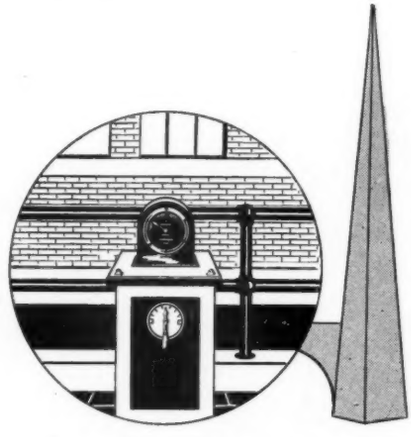
VENTURI



Remote Control of Pumping Stations

You can set operation of a distant pumping station without leaving your office; Instruments right at your elbow will report back exactly what is taking place.

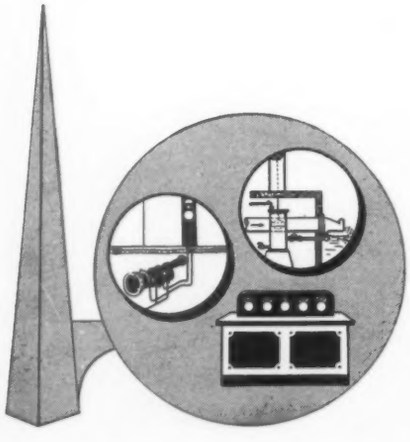
VENTURI



Master Control of Filters

You can set an entire group of filters through one central Master Controller; or have the level of the clear well take over the control.

VENTURI



Air Relay — Kennison Nozzle — Ratio Gauges

You can measure sewage and sediment-bearing water with Air Relay Transmission. You can measure flow through partially filled pipes with Kennison Nozzles. Flow and Ratio Gauges will contribute effectively to efficiency of sewage treatment.

Atlantic City — AWWA — Booths 109-110

You can ask Builders representatives about your metering and controlling problems—or write for descriptive bulletins.

BUILDERS IRON FOUNDRY
PROVIDENCE, RHODE ISLAND

Guarantees:

Powdered: phenol value of 14

Granular: phenol number not less than 9

The Super-

ACTIVATED CARBON

NORIT . . . a "made in America" activated carbon for taste and odor control is shipped to users with the above guarantees.

These qualities certainly place NORIT in the Super-Activated Carbon class. That it is a more effective and more economical carbon is evidenced by the fact that such plants as the following are using it regularly: Cincinnati, Atlanta, Salem (Mass.), Flint, New Brunswick, Hackensack Water Co., and others.

Our technical representatives will be at the Atlantic City Convention (Booth 22) and will be glad to discuss the application of NORIT at your waterworks.

Sales Agents
for
AMERICAN NORIT CO., Inc.
551 Fifth Ave., New York
Plant: Jacksonville, Fla.

L. A. SALOMON & BRO.

216 Pearl St. New York, N. Y.

% PROPORTIONEERS % CHEMICAL FEEDER No. 1939

(dressed up like the World's Fairs) for shipment to Armour Tech's Research Foundation —

We're proud of our baby! And we're proud of all his nearly 2000 brothers for they have given us an accumulated experience in the feeding of chemicals of all kinds which few, if any, other organizations can equal.

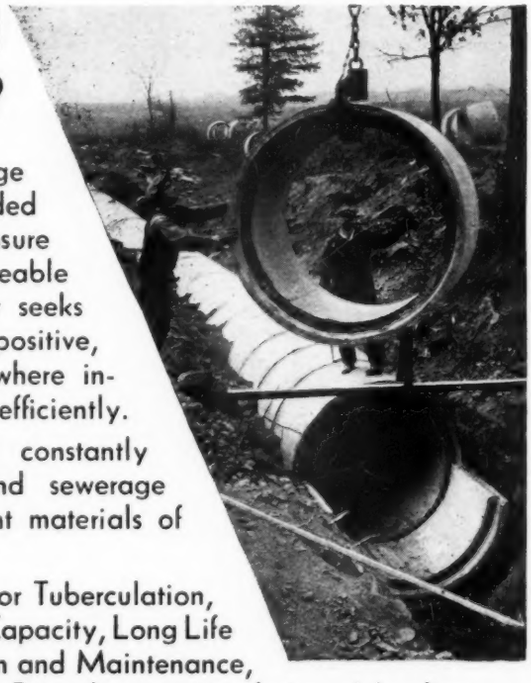
These two shown here will enjoy an interesting life. The automatic proportional meter-operated feeder will "corrupt" the laboratory water supply and the heavy duty midget will be used by the students, under Prof. Vogtborg's direction, to experiment with the results of feeding alum, soda ash, hypo-chlorite, and other solutions.

BOOTH 112
A. W. W. A. ATLANTIC CITY

Engineers in attendance will gladly discuss the application of % Proportioneers % Chemical Feeders to your water treating job. Profit by their experience!

% PROPORTIONEERS, INC. % *Associated With Builders Iron Foundry*
9 CODDING STREET, PROVIDENCE, RHODE ISLAND

IS YOUR CITY UP TO DATE IN WATER SUPPLY AND SEWERAGE?



DON'T be dependent on antiquated systems. The average citizen is no longer content to wade through flooded streets in times of storm, nor is he satisfied with low pressure water service, discoloration and noticeable tastes or odors. Likewise, Big Industry seeks those communities where there is positive, ample supply of good water and where industrial wastes are disposed of efficiently.

Forward looking Cities will constantly improve their water supply and sewerage facilities, using modern, efficient materials of construction.

Freedom from Corrosion or Tuberculation, Permanently High Carrying Capacity, Long Life and Economy of Installation and Maintenance, make Lock Joint Concrete Pipe the premier choice of leading Cities and Industries for their important water or sewer mains.

PRESSURE • SEWER • SUBAQUEOUS • CULVERT
LOCK JOINT PIPE CO. AMPERE, N. J.

LOCK JOINT *Reinforced* **CONCRETE PIPE**

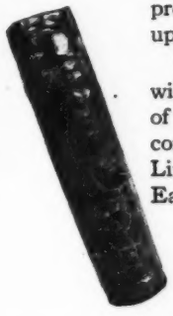
FOR EFFECTIVE PIPE PROTECTION

COATINGS must be WRAPPED with ASBESTOS FELTS

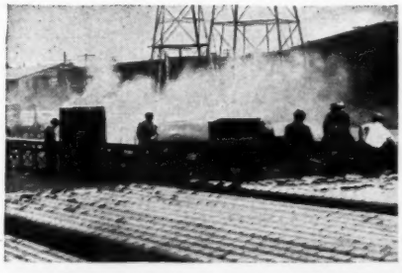
● Here's a money-saving tip to waterworks engineers. More than 25 years' experience in the oil and gas industries has proved many types of ferrous pipes must be protected by a corrosion-resistant coating. What's more, the coating must be reinforced or shielded with a strong, durable wrapping to prevent distortion and abrasion. And, for that service, asbestos—in the form of J-M Pipe-Line Felts—has proved the ideal material.

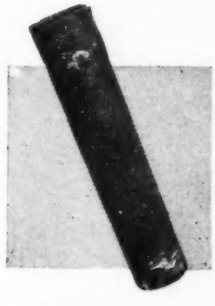
Because the asbestos fibers are inorganic and non-tubular, J-M Asbestos Felt cannot support capillary action. Tough and durable, it reinforces the coating against earth load and soil stress. And, because it is exceptionally resistant to the corrosive action of soil acids and alkalis, this durable felt gives efficient protection for the coating . . . helps keep upkeep costs to a minimum.

You'll be interested in the whole story. It will show you why more than 30,000 miles of pipe are operating at low cost under severe conditions. Write for the J-M Asbestos Pipe-Line Felt brochure to Johns-Manville, 22 East 40th Street, New York, N. Y.



UNWRAPPED BITUMINOUS COATING after exposure to clay-content soil. Soil stress has destroyed much of the protective coating.





THE SAME COATING, under the same conditions, but wrapped with J-M Asbestos Felt. The wrapping shows no signs of breakdown . . . the coating underneath is practically as good as new.

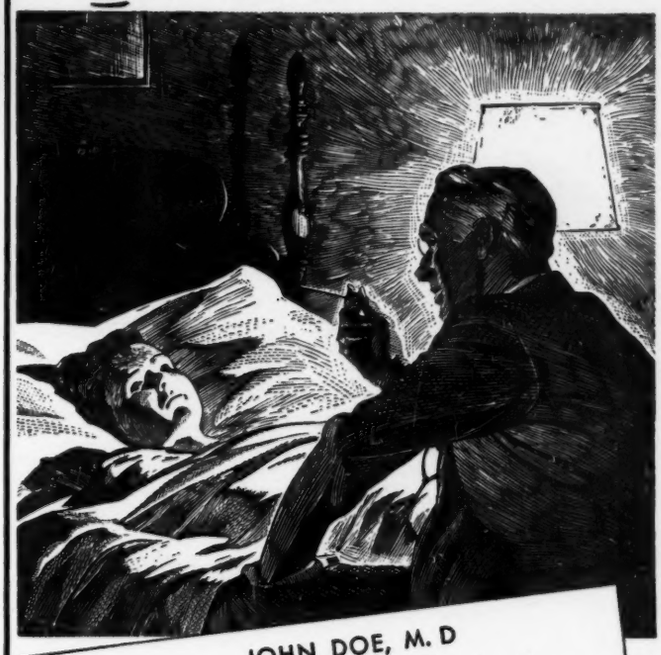
YOU CAN PURCHASE pipe from the steel-pipe mill coated with any standard coating material and wrapped with Johns-Manville Asbestos Felts. Or the same operation can be performed in your own yard by portable wrapping equipment supplied on a rental basis. Write Johns-Manville, 22 East 40th Street, New York, N. Y., for further information.

JOHNS-MANVILLE JM

ASBESTOS PIPE-LINE FELTS

"C'MON IN, DAN, THE WATER'S SWELL"

(BUT IT WASN'T SO CLEAN)



JOHN DOE, M. D

Patients Record

Name Harvey, Edward Age 11
416 Pine St

Examination Temp 104, Pulse slow, Blood count shows leukopenia*. Mother states child has had only pasteurized milk. Has been swimming daily in Johnson's Creek where town Sanitation Committee recently discovered typhoid bacilli—

*Reduced white blood corpuscles.

Johnson's Creek might be any creek or stream throughout the country—Edward Harvey, any American boy . . .

Pollution of streams by sewage (and some insufficiently purified effluent from plants) is fast becoming a major problem. *Be doubly certain!* Purify all effluent from disposal plants with Solvay Liquid Chlorine!

Immediate shipments of Solvay Liquid Chlorine are available in cylinders or tank cars for swimming pools, sewage and water purification plants.

SOLVAY SALES CORPORATION

Alkalies and Chemical Products Manufactured by The Solvay Process Company

40 RECTOR STREET NEW YORK, N. Y.

Branch Sales Offices:

Boston • Charlotte • Chicago • Cincinnati • Cleveland • Detroit • Indianapolis
New Orleans • New York • Philadelphia • Pittsburgh • St. Louis • Syracuse

SOLVAY

TRADE MARK REG. U. S. PAT. OFF.

LIQUID CHLORINE

EQUIPMENT NEWS

"Sani-Pac" (A Bugless Joint Packing)

● "FLEX-SANI-PAC" bids fair to end the worries of those experiencing bacterial "aftergrowths" in purified water during passage through mains or the distribution system—or at least those "aftergrowths" which originate in the materials commonly used for packing poured joints.

"FLEX-SANI-PAC" is the name coined by the inventor of the new sanitary "yarning" material—Hayes R. Kuhns, of Killbuck, Ohio. Kuhns' bugless joint pack involves the use of cut lengths of heavy walled tubing of live-rubber, which is lapped around the spigot and pushed home with the caulking iron—and in as little time as it takes to tell it. The result is a sealed water-free annular space of uniform dimensions (spigot to bell) for the usual joint pouring in the regular fashion. Chemists like it because it is clean, and a poor host to trouble-making aftergrowths. Joint-makers like the method because of its simplicity and ease of "yarning up."

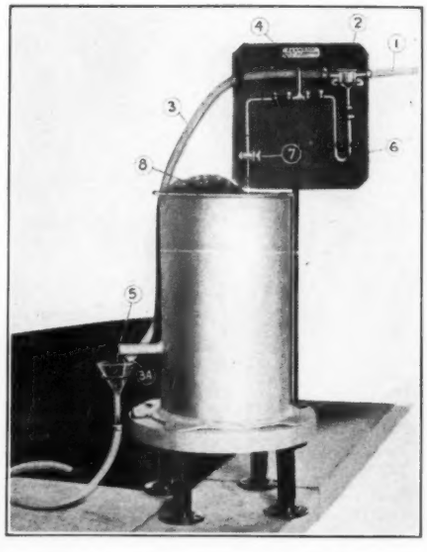
In an article appearing in this same issue, V. K. Calvert, Chemical Engineer of The Indianapolis Water Co., more effectively describes this new scheme of jointing with Kuhns' "Sani-Pac" rubber tubing, which to our thinking is a contribution worthy of high interest. We commend the inventor, whose chief aim was that of doing something in the interest of cleaner water, and fewer harassed operators.

For further information write Hayes R. Kuhns, Killbuck, Ohio. We understand that demonstrations of his "Sani-Pac" method will be made at Leadite Co.'s booth at the Atlantic City Convention, June 11-15, by Mr. Kuhns himself.

NOVEL CHEMICAL FEEDER Control Based on Feeding Saturated Solutions

● The Economy Chemical Feeder is new. It makes use of the principle of regulating nothing more corrosive than a water stream, which in turn displaces at the rate set an equal volume of saturated solution of the chemical to be fed.

Advantages claimed are the following: (1) Water feed control is simple and easy to maintain at rates set; (2) the chemical solution flows through large orifices and tubes, which precludes difficulties encountered from corrosion and depositions in small control orifices, needle-valves and the like; (3) A large reserve capacity of chemical for long period service between re-chargings; thereby, space conservation in installations of size and minimum attention.



Elsewhere in this issue is an article on copper-sulphate feeding by Mr. Paul Weir, wherein is described a very similar feeder perfected at and successfully employed in the Atlanta plant. For further details read Mr. Weir's article, and also write Economy Manufacturing Co., Box 188, Chattanooga, Tenn.

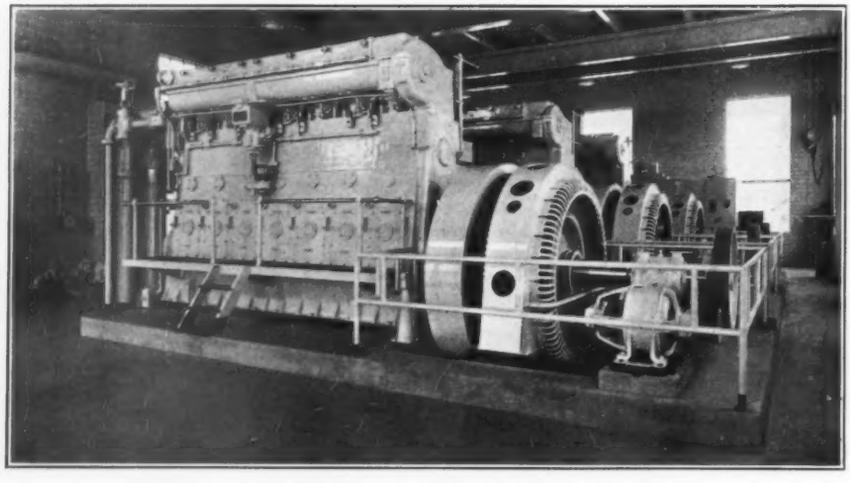
Unbreakable Manometer

● The Connelly Iron Sponge & Governor Co. of Chicago, Ill. and Elizabeth, N. J., are offering an improved Universal U Gauge (Manometer), designed for portable or stationary use, and either as a pressure or head differential gauge. A feature of this instrument is its clear unbreakable glass-like tubing, and its sturdy construction to withstand rough handling.

These Universal Gauges are available with both 3/8 in. and 5/8 in. tubing, in a wide range of sizes. They may be had plain

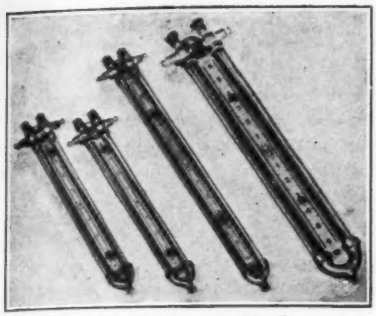
Rathbun Sludge-Gas Engines

Sizes: 225 H.P.—2150 H.P.



Three 500 KW Units, City of Columbus, Ohio

THE RATHBUN-JONES ENGINEERING COMPANY
Toledo, Ohio



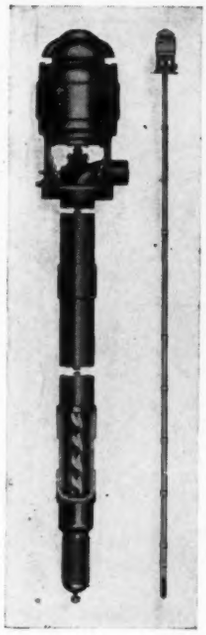
Connelly Universal U Gauge

for stationary use, or fitted with valves for portable use or to serve as differential gauges. Since the trend is to provide more such gauges on gas lines of sewage treatment plants, this announcement should interest operating as well as designing engineers.

Among the features claimed for these new gauges are: Unbreakable tubing is fitted with standard pipe treads so tubes can be screwed into metal attachments without packing glands or gaskets; needle-valves at top retain fluid for portable use; full protection for the special tubing which is amply strong to withstand pressures to 100 lbs.; easily read graduated scale of etched metal, movably attached.

A new bulletin fully describes and illustrates these gauges, listing prices and full information. For a copy of Bul. No. 401 B-1 write Connelly Iron Sponge & Governor Co., 3154 So. California Ave., Chicago, Ill., or 200 So. Second St., Elizabeth, N. J.

THE PEERLESS "HI-LIFT"



"Hi-Lift" is the name given a new Peerless deep well pump recently put on the market.

The new pump is neither a turbine or a plunger pump, but is claimed to combine the advantages of both, for small diameter well installations where lifts from 5 to 50 g.p.m. are desired against heads up to 1000 feet. The low speed operation (1750 r. p.m.) is emphasized. The unit, which will go into wells as small as 3 in. diameter, is equipped with a novel lift element consisting of a helical-contoured stainless steel rotor revolving inside of a helical-contoured stator of cutless rubber. As the rotor revolves the water is "squeezed" upward through the spiral passageways created with the turning of the helical rotor.

For a much clearer description of this novel unit, request "HiLift" bulletin 142. Write Peerless Pump Div., (Dept. 109),

Improved "Turco" Sewer Flusher

● Turbine Sewer Machine Co. of Milwaukee announce an improved model of the well known "Turco" Sewer Flusher,

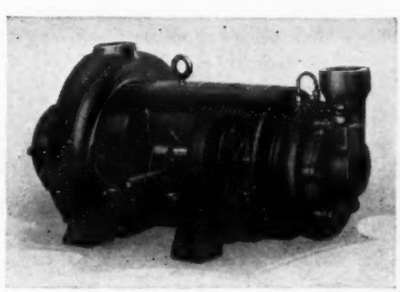
which consists of a flushing nozzle on a collapsible bag connected by hose line from sewer to the nearest fire hydrant.

The improved "Turco" has a mildew-proof bag of tougher construction than the heavy canvas bags of former years. The outside cover bag is of tough rubberized duck, within which is a quadruple stitched four-ply canvas sack containing an improved inner tube. In addition, stronger bands have been applied with an especially constructed hydraulic banding machine, which develops 2,000 pounds pressure.

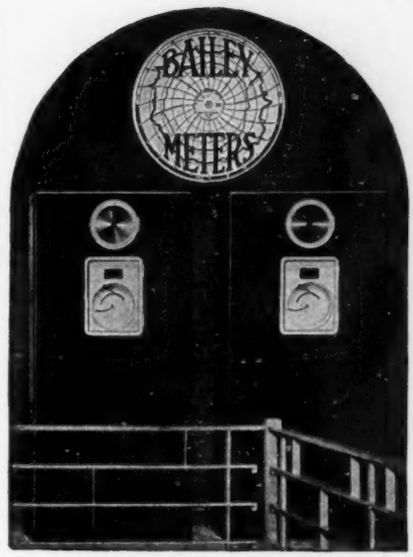
For a better description of the improved "Turco" Flusher and complementary sewer cleaning equipment, write for the most recent Turbine Catalog, address Turbine Sewer Machine Company, 5210 West State St., Milwaukee, Wisc.

NEW EXPLOSION PROOF WORTHINGTON CENTRIFUGAL

● To its line of compact "Monobloc" centrifugals Worthing has added a new model. These are especially designed for service in locations where explosion risk may exist. Therefore, as utility units around sewage plants, they merit interest by designers and operators.



Capacities of the new "Monoblocs" vary from 10 to 400 g.m.p. against heads of 10 to 240 ft. For more complete description of these compact safety units, ask for Bul. W-321, B 3, Worthington Pump and Machinery Corp., Harrison, N. J.



When You Specify

Meters and Recorders

Be Sure To Demand

● ACCURACY ● RELIABILITY
● SOUND ENGINEERING
● MODERN APPEARANCE

Regardless of whether your problem calls for the use of a Venturi Tube, Weir, or Flume, you can depend on Bailey Meter Company to design and construct both the primary element and the register for maximum accuracy.

A vast amount of experience gained from thousands of installations of metering equipment, together with extensive experimental work in our own hydraulic laboratory and in the laboratories of the Ohio State University, Cornell University, Case School of Applied Science and other institutions, is back of every Bailey Primary Element.

The reliability of Bailey Meters and Recorders is attested to by the fact that thousands of dollars worth of steam and water are sold monthly and billed solely on the basis of readings from Bailey Meters.

No small share of the accuracy and reliability of Bailey Meters is due to the conservative engineering policy of the Company. New ideas and designs are not offered for sale until they have been thoroughly tested both in the laboratory and in actual service.

Bailey Meters, Recorders and Controllers present a thoroughly modern yet conservative appearance.

Write for your copy of Bulletins No. 301 and 302, describing Bailey Fluid Meters for steam, liquids, gases, sewage, sludge, and compressed air.

MU-16

BAILEY METER COMPANY

1072 Ivanhoe Road, Cleveland, Ohio

BAILEY METER COMPANY LTD., MONTREAL

COMPLEX or SIMPLE

All Joints look alike to this* INGOT *Form Compound

Tegul-MINERALEAD is used in pipe from 2" diameter up to the largest—and in every size in between. It is easy to use; no skilled labor required; no caulking or deep bell holes needed ● Correctly compounded at our plant, no amount of jolting in transit can change composition en route to you ● The 10 lb. unit is easy to handle, ship and store; and impervious to rain and flood ● Tegul-MINERALEAD offers the conceded advantages of sulfur base compounds without their handicaps ● Initial leakage heals quickly, permitting immediate clean-up ● For further information write the ATLAS MINERAL Products Company of Penna., Mertztown, Pennsylvania.

A Tegul PRODUCT

Tegul-MINERALEAD

WITH THE MANUFACTURERS

A WORLD'S FAIR NUMBER (Midget No. 1939)

● On another page of this issue is the story of Proportioneers' ornately embellished Heavy Duty Midget (here pictured) which bears Serial Number 1939 and, in consequence, christened "The World's Fair Midget."

This little machine, made even more ornate by its dressy cellophane wrappings and ribbon, scintillates with a trim of chrome plate applied to all exposed metal parts. When the 1939th Midget came off of the production line in Providence it was ear-marked for the Research Foundation at Armour Institute of Technology in Chicago—the 1939 serial number giving the inspiration to add the "touch of tomorrow" and dub it "The World's Fair Midget." Henceforth, this show unit will be on permanent display in Professor Vagtborg's Sanitary Engineering Laboratories at Armour Institute, where it will be in use in connection with the operation of the experimental treatment plant.

Announcement Concerning Conkey Vacuum Filters

● The Goslin-Birmingham Manufacturing Company, Inc., announce that they are now exclusive manufacturers and distributors of the Conkey Vacuum Filters. This includes rotary drum filters, rotary hopper dewaterers, open tank leaf filters and cataphoric filters.

Goslin-Birmingham have been filter manufacturers for many years, and now they will sell their filters to the industrial and sewage fields direct. G. D. Dicky, formerly with Filtration Equipment Corporation, is in charge of filter sales with Goslin-Birmingham.

Headquarters—350 Madison Ave., New York City, N. Y.

FERRIC ISCO CHLORIDE

Simple to Use • Low in Cost

IN SLUDGE CONDITIONING — Better Performance at reduced cost, including that of dewatering equipment. Boosts filtration rate.

In COAGULATING SEWAGE — Flexibility to handle plant overloads. Greater removal of suspended solids. Improved effluent.

In WATER FILTRATION — A practical and economical coagulant, giving quick forming, fast setting floc.

INNIS, SPEIDEN & CO.
117 LIBERTY STREET, NEW YORK, N. Y.
Chicago Cleveland Boston
Philadelphia Gloversville, N. Y.

PHOENIX DISC WATER METERS

Are proving their true economy to exacting Water Superintendents.

SPIRAL GEARS—Just as the Automobile Industry uses Spiral Gears in the Car you drive, to eliminate friction and obtain smooth quiet operation, we employ Spiral Cut Gears and have obtained the same results. Spiral Gears are a patented feature in Phoenix Meters.

Let us show you point for point, just how Phoenix Meters can and will prove to be a truly economical Meter.

UNION METERS—Did you know we furnish Repair Parts for Union King Meters formerly manufactured by the Union Meter Company. Write us for prices on our Repair Parts.

PHOENIX METER CORPORATION
Established 1914
Prince Bay, S. I.,
New York, N. Y.

CARTER

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Humdinger Diaphragm
Plunger

Self Priming Centrifugal

PUMPS

Alternating Syphons
Aerators

Above Mfgd. by Ralph B. Carter Co.
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Sewage Pumps
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Sump Pumps

RALPH B. CARTER CO.
Sales Office
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Main Office and Factory
195 Atlantic St. Hackensack, N. J.

Chicago Bridge & Iron Appoints Williams Special Engineer on Morse Filter Plants

● The Chicago Bridge & Iron Company has transferred Richard A. Williams, formerly sales engineer at the company's Tulsa office, to its Main office in Chicago. Mr. Williams will serve as special engineer on Morse filter plants of all steel construction.

Previous to his service in the Tulsa office, Mr. Williams served as sales engineer in the Chicago and Philadelphia offices of the company. At Philadelphia, he was in close contact with the design and installation of the two 5 mgd units of the Washington Suburban Sanitary District, at Burnt Mills, Maryland.

Mr. Williams' new duties will consist primarily of co-operating with consulting engineers in the design of steel filter plants.

COLUMBIA ALKALI BOASTS NOVEL OFFICE BUILDING

● The accompanying photog aph was taken of the lobby of the spiffy new office building, completed recently at the Barberton (Ohio) Works of Columbia Alkali Corporation. More properly the Columbia Chemical Div. of Pittsburgh Plate Glass Co., this fact is emphasized in the condensed history of the Division which appears etched into the hanging plate glass in front of the large mirror. Note the liberal use of Pittsburgh-Corning glass wall blocks, and the inside walls faced with carrara glass plates in gray, with trim plates in maroon. The ceiling is painted with "Wallhide", another Pittsburgh Plate product. The furniture, too, is of maroon leather with chrome metal trim.

The Columbia plant at Barberton was established as an alkali works in 1900 but not until 1936 was liquid chlorine produced.

POSITION WANTED

Graduate Civil Engineer, with 13 years in municipal and sanitary engineering desires association with consulting engineer. Recently completed large water supply project, as engineer in charge of design and construction. A.A.A., % Water Works and Sewerage, 155 East 44th St., New York City.

Luippold Appointed West Coast Agent Everson Chlorinators

G. T. Luippold

● Announcement has been made by Everson Manufacturing Co. of Chicago, that the Luippold Engineering Sales Co. of Los Angeles has been appointed exclusive Everson representatives in California. The Luippold Company will sell, install and service Everson chlorinators and ammoniators and ammoniators.

G. T. Luippold, president of the company which bears his name, was for many years Southern California representative of the Wallace & Tiernan Co., before he resigned to establish his own company. He has built a reputation for conscientious sales and service and has many friends in California. Back again in the chlorinator and ammoniator business, "Lui" is probably feeling like Uncle Remus' "Br'er Rabbit," that "Mr. Mann," having caught on a tar-baby in his cabbage-patch, threw out of the window into the briar-patch—"whar he were born and bred."

National Distribution For Bingham Pumps

George R. Alexander Heads Eastern Division

Geo. R. Alexander

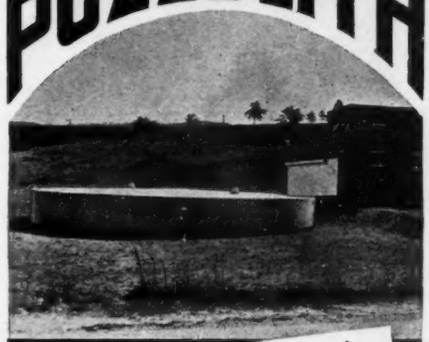
● With the establishment of twenty-five distributors in leading cities throughout the United States, and the opening of direct factory offices in New York City, the Bingham Pump Company, Portland, Oregon, this month completed the biggest expansion program in the company's long history.

George R. Alexander, engineer and former executive vice-president of the Byron-Jackson Company, is in direct charge of eastern sales and Bingham's New York office.

The latest development of Bingham's engineering staff, headed by Carl Bloom, is the "Bingham Submersible," a pump that operates automatically under water as well as in air. The novel "Submersibles" have been greeted with enthusiasm because they require but little attention or maintenance, require no housing structures above ground, and are free of shaft and bearing problems.

The New York office is located in The Graybar Bldg., 420 Lexington Ave.

POZZOLITH



4,500 Sq. Ft. of CONCRETE SURFACE.. Not One Square Inch of HONEYCOMB

● "Pozzolith has been very satisfactory" report Boyd & Goforth, Inc., Engineers, Charlotte, N. C. "It was used at Valdese, N. C. in the 200,000 gallon reinforced concrete clear well, and in all concrete for the 500,000 gallon per day water purification plant.

"We reduced the water ratio . . . The workability of the concrete with Pozzolith was far superior . . . The 200,000 gallon reservoir was poured one day and the forms stripped the next afternoon . . . In approximately 4500 square feet of exposed concrete surface, not one square inch of honeycomb was found."

Boyd & Goforth's statement is typical of many job case histories that report exceptionally fine results with Pozzolith. Send for facts that will help on your jobs.

PROOF OF EXTRA DURABILITY

Pozzolith concrete is durable concrete! 200 cycles of freezing and thawing prove the greater durability imparted to concrete by Pozzolith. Pozzolith concrete lost only 2% in weight . . . plain concrete lost 22.9%!

Send for full information to

THE MASTER BUILDERS COMPANY
Cleveland, Ohio

In Canada: THE MASTER BUILDERS Co., Ltd.
Toronto, Ontario

MASTER BUILDERS

Handle Chemicals Cheaper and Better

by the MODERN

DRACCO Pneumatic Conveyor Way

Many Water Works Engineers have found DRACCO Pneumatic Conveyors the most efficient and economical way of handling their Chemicals.

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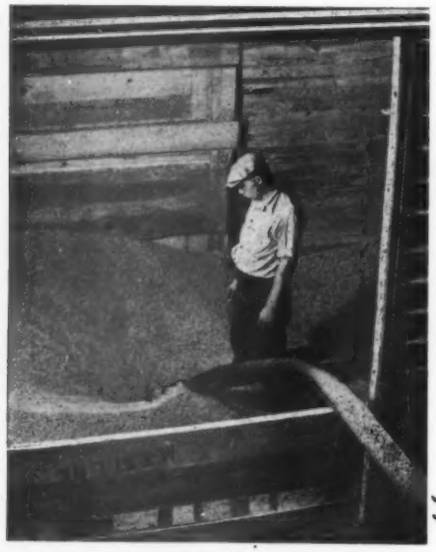
FRIDLEY FILTRATION PLANT.....Minneapolis, Minn.
DALECARLIA FILTRATION PLANT.....Washington, D. C.
MUNICIPAL WATER SOFTENING PLANT...Sandusky, Ohio
MUNICIPAL WATER SOFTENING PLANT.....Ames, Iowa
LEMIEUX ISLAND FILTRATION PLANT...Ottawa, Ontario
MAHONING VALLEY SANITARY DISTRICT....Niles, Ohio
MUNICIPAL WATER PLANT.....Columbus, Ohio
MUNICIPAL WATER PLANT.....Peru, Ill.
U. S. GOV. FILTRATION PLANT....Ft. Leavenworth, Kan.
MUNICIPAL WATER PLANT.....Hamilton, Ohio
BACHMAN WATER PURIFICATION PLANT..Dallas, Texas
MUNICIPAL WATER PLANT.....Richmond, Va.
MUNICIPAL WATER PLANT.....Springfield, Ill.
MINNEAPOLIS-ST. PAUL SANITARY DIST..St. Paul, Minn.
(Sewage Disposal Plant, 2 installations)
MUNICIPAL WATER PLANT (2 installat'ns)..Milwaukee, Wis.
MUNICIPAL SEWAGE DISPOSAL PLANT..Okla. City, Okla.
MUNICIPAL SEWAGE DISPOSAL PLANT.....Denver, Colo.
MUNICIPAL WATER PLANT.....Covington, Ky.
MUNICIPAL WATER PLANT.....Ann Arbor, Mich.
CLAYTON SEWAGE DISPOSAL PLANT.....Atlanta, Ga.
WESTERLY SEWAGE DISPOSAL PLANT...Cleveland, Ohio
EASTERLY SEWAGE DISPOSAL PLANT....Cleveland, Ohio
MUNICIPAL WATER PLANT.....Benton Harbor, Mich.
MUNICIPAL SEWAGE DISPOSAL PLANT.....Detroit, Mich.
MUNICIPAL WATER PLANT.....Warren, Ohio
CITY OF TORONTO WATER WORKS PLANT.Toronto, Ont.
WATER SOFTENING PLANT.....Flint, Mich.
WATER FILTRATION PLANT.....Ottawa, Kan.
EL RENO WATER TREATMENT PLANT.....El Reno, Okla.



Write for Bulletin No. 526

• For Further Information Write •

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MEETINGS SCHEDULED

June 5-9—Raleigh, N. C. (N. C. State College)
North Carolina Water Works School. D. S. Abell, Prin. Ass't. Engr., State Board of Health, Raleigh, N. C.

June 11-15—Atlantic City, N. J. (Hotels Ambassador and Chelsea—Meetings and Exhibits in Auditorium)
American Water Works Association. (59th Annual Convention.) Executive Sec'y. Harry E. Jordan, 22 East 40th St., New York City.

June 26-28—State College, Pa. (Nittany Lion Inn and Dormitories.)
Pennsylvania Sewage Works Ass'n. Sec'y-Treas., L. D. Matter, Distr. Eng'r., Kirby Health Center, Wilkes-Barre, Pa.

June 28-30—State College, Pa. Nittany Lion Inn and
Pennsylvania Water Works Operators' Association. Sec'y-Treas., I. M. Glace, 22 South 22nd St., Harrisburg, Pa. Dormitories)

Aug. 24-25—Duluth, Minn. (Hotel Duluth)
Minnesota Section A.W.W.A. Sec'y-Treas., R. M. Finch. W. & T. Co., 416 Flour Exchange, Minneapolis, Minn.

Sept. 12-15—Montreal, Quebec, (Hotel Windsor)
New England Water Wk's. Ass'n. (Annual Convention). Sec'y, Frank J. Gifford, 613 Statler Bldg., Boston.

Sept. 20-22—Lansing, Mich. (Olds Hotel)
Michigan Section A.W.W.A. Sec'y, M. N. Gerardy, Water Board Bldg., Detroit, Mich.

Meeting Jointly with
Michigan Conference Water Purification. Sec'y-Treas., R. J. Faust, Michigan Dept. Health, Saginaw, Mich.

Sept. 25-26—Dickinson, N. D.
North Dakota Water & Sewage Conference. Sec'y-Treas., L. K. Clark, Bismarck, N. D.

Oct. 5-6—Reading, Pa. (Berkshire Hotel)
Four States Section A.W.W.A. Sec'y-Treas., Carl A. Heckmer, Washington Sub. San. District, Hyattsville, Md.

Oct. 9-11—Pittsburgh, Pa. (Hotel Wm. Penn)
American Public Works Association, Exec. Director, Frank W. Herring, 1313 East 60th St., Chicago, Ill.

Oct. 11-13—Kansas City, Mo. (Hotel President)
Missouri Valley A.W.W.A. Sec'y., Earl L. Waterman, University of Iowa, Iowa City, Ia.

Oct. 16-19—Dallas, Texas
Southwest Section A.W.W.A. Sec'y-Treas., Lewis A. Quigley, 3320 West Berry St., Fort Worth, Texas.

Oct. 17-20—Pittsburgh, Pa. (Hotel William Penn)
American Public Health Association. (68th Annual Meeting.) Exec-Sec'y., Dr. Reginald M. Atwater, 50 West 50th St., New York City.

Oct. 19-21—Atlantic City, N. J. (Hotel Haddon Hall)
Pennsylvania Water Works Association. (Annual Meeting.) Sec'y, F. Herbert Snow, 507 Telegraph Bldg., Harrisburg, Pa.

Oct. 19-20—Hamilton, Ont. (Royal Connaught Hotel)
Canadian Institute on Sewage & Sanitation. Sec'y-Treas., A. E. Berry, Ontario Dept. of Health, Parliament Bldgs., Toronto, Ont.

Oct. 20-21—Atlantic City, N. J. (Claridge Hotel)
New Jersey Section A.W.W.A. Sec'y, H. N. Lendall, Rutgers University, New Brunswick, N. J.

Oct. 25-28—San Francisco, Calif.
California Section A.W.W.A. Sec'y-Treas., Burton S. Grant, Civil Engr., Bureau of Water, Los Angeles, Calif.

Oct. 30-Nov. 1—Oshkosh, Wisc.
Wisconsin Section, A.W.W.A. Sec'y-Treas., Leon A. Smith, Supt., Water Dept., City Hall, Madison, Wisc.

CATALOGS AND LITERATURE

"Metering Practices"—A Manual setting forth proven practices in specification; purchase; installation; maintenance; repair; testing; selection of correct meter for the service at hand, etc. This, in a measure, describes the most complete and worthy compendium on "Metering Practices" that it has been this writer's privilege to examine. The handy size (6 x 9 inch) book of 108 pages, neatly bound and effectively illustrated, does full credit to the authority who compiled it—Mr. Henry Horandt, C. E., Meter Engineer of the Federal Water Service Corp., and manager of one of its most important properties. And, from its readers, appreciation in full measure will go to the company which has published and is distributing this valuable manual of practice at no charge.

The author in a foreword states: "The detailed procedures are offered for what they may be worth and are designed for the numerous persons interested in meters, who would like to know *what the other fellow is doing* as a matter of comparison with their own methods." * * * "An effort has been made to review the fundamentals in order to present a clearer picture of the problem as a whole." We say that these efforts, and many others, have been met by the author. More words here could add but little; so we can best say to all interested—if you can't beg a copy of Horandt's "Meter Practices," get one the next best way. Then, nail it down, lest it turn up missing some day. To get your name on file for a copy write Neptune Meter Co., Rockefeller Center, New York City, N. Y.

"The Meter-Master"—dubbed by operators "The Water Works G-Man" is presented in an easy to read booklet from F. S. Brainard & Co. of Hartford, Conn. The "Meter-Master" was conceived by inventor F. S. Brainard, Distribution Engineer of Hartford's Water Department, who developed this interesting rate recorder for the Department's use. Its value was soon recognized by other water works operators, with the result that production was started by a company organized by the inventor. The little booklet then goes on to describe the instrument which has proven so useful in settling disputed water bills; checking meters for correct type or size; detecting water waste on outlying sections of distribution systems; for meter field-testing, and allied adaptions. The booklet announces a new type of instrument for making recordings covering periods longer than 72 hours, or for maximum accuracy of checkings. Quoting from "Round Table" discussions, users' opinions of the "Meter-Master" are voiced. We continue to believe that "Every Water Works Needs a G-Man"; and, think that after reading the booklet many others will agree. For a copy, write F. S. Brainard & Co., 246 Palm St., Hartford, Conn.

"Equipment for Water and Sewage Plants"—is a new catalog which pictures and describes water works and sewerage equipment produced by Jeffrey Mfg. Co., including mechanical bar screens; sludge and scum removal mechanisms for settling tanks; screenings grinders; grit washers of two types (V-bucket and the new jig-type); sludge elevators; "Waytrol" chemical feeders, equipped with vibrating hoppers. The absence of Jeffrey's new "Floctrol" mechanism for flocculation control from the catalog is noticeable. For a copy of Catalog 703 write Jeffrey Mfg. Co., Columbus, Ohio.

FARNAN
ESTABLISHED IN 1852
BRASS
FOR EIGHTY-SEVEN YEARS

A complete line of brass fittings for all water works needs. All types and sizes for lead, iron or copper services.

All our products are cast from 85-5-5-5 Ingot, accurately machined to gauges and tested at 200 pounds hydrostatic pressure.

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The FARNAN BRASS WORKS CO.
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Eliminate SULPHUR DAMAGE

Connelly IRON SPONGE

If you are making use of sewage gas in your plant you should protect your valuable equipment from deterioration by the Connelly method of gas purification. This costly damage can be and is being eliminated in many plants throughout the country, and Connelly engineers, with more than 50 years' experience in successfully handling purification problems, can show you how this deterioration can be stopped — easily — efficiently — and most economically.

The services of the Connelly Engineering Department are available for consultation on any purification problem without cost or obligation and you are invited to make use of this service at any time.

Other Connelly Products

The Connelly Manometer or U Gauge is designed for rough usage yet retains the fine qualities of precision, accuracy, and utility. Write for Bulletin No. 401-B-1 which describes the complete line showing sizes, etc.

The Connelly H2S Tester provides a single, accurate, and convenient method of testing, giving you a permanent record for future reference. Our illustrated bulletin gives complete information.

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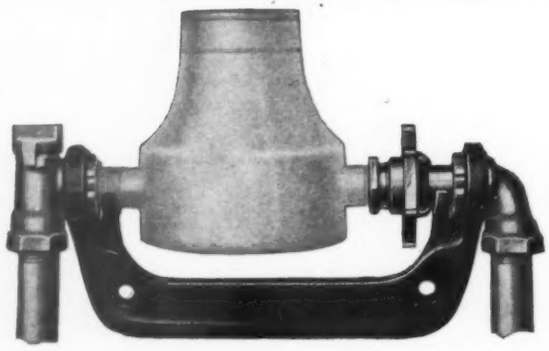
Ford YOKES



Ford Yokes have been made for over twenty-five years and have features which make them preferred in many hundreds of progressive waterworks. Let us give you further information about what Ford Yokes will do for you.

Ford Meter Box Co.
SETTING AND TESTING EQUIPMENT FOR WATER METERS
WABASH, IND., U.S.A.

"Corrosion Control"—is Philadelphia Quartz Company's presentation of the role of sodium silicate in water treatment to check corrosion. Methods of application, effective dosages, testing for correction control, pictures of feeding equipment, typical installations and results, are discussed. Especially stressed is the fact that slight overtreatment results in no ill consequences, that treatment need not be continuous, that no objecttionable hardening of water results. Interesting paragraph on "Length of Carry," reveals that silicate effectiveness reaches remote sections of the pipe system and extends through to the consumers' hot water services—in the case cited the effect reaching undiminished at the end of a seventeen mile carry, through the supply main, and into the distribution system. For a copy of P. Q. Bul. No. 373, which also recites case records, write Philadelphia Quartz Co., 121 South 3rd St., Philadelphia, Pa.

"Meter Performance Standards"—Are discussed in an interesting manner in Pittsburgh Meter's newest booklet, which stresses house-meter deficiencies at low flows and at leakage rates. Effective are the tabulated figures revealing the high cost of low flow accuracies (1440 minutes a day) when comparing 70% and 85% recordings. All of this leads up to the reason behind the novel Pittsburgh "I M O" meter which has proved of wide interest although only announced to the trade a year ago. The scheme of showing the interior construction of the "I M O" in two colors is further supported by accuracy curves showing that the dribble-catching "I M O" starts at 90%, reaching 98% accurately at ¼ g.p.m. flows. For a copy of "Meter Performance Standards" write Pittsburgh Equitable Meter Co., 400 North Lexington Ave., Pittsburgh, Pa.

"Manhole Conscious?"—is the pertinent question raised by Tapax Mfg. Co., makers of "Tapax"—a cushioning tape for silencing banging manhole lids; also sealing leaking lids which surcharge sewers during storms to a little realized degree—(See Rawn. "Water Works & Sewerage" for Dec. 1937 p. 459.) This lethargy dispelling leaflet cites the case against banging manhole lids and those who ignore the public nuisance, if nothing more serious. The leaflet describes the wire reinforced asbestos adhesive "Tapax" tape; lists many satisfied users; gives two line testimonials as to why. Readers who have banging manhole lids and want to know what to do about it can learn by writing "Tapax" Mfg. Co., 201 Hoyt Ave., Mamaroneck, New York.

"Link-Belt Screens" are presented in a folder from Link-Belt Company. First there are the well known "Straightline" mechanically raked automatic bar-screens, with specifications and detailed drawings. Then follows the newer "Tritor Screen" which is a combination screen and grit chamber equipped with adjustable baffles to maintain grit separating velocities. It is also mechanically cleaned. For folder No. 1587 write Link-Belt Co., 2045 Hunting Park Ave., Philadelphia, Pa.

"Pomona's Little Chief"—is the newest Pomona well pump covered in the newest Pomona bulletin. The "Little Chief" is in all respects of the same design as the larger Pomona Deep Well Turbines. It has been produced to fill the need for such units on the smaller public andi ndustrial supply systems;

and, large private systems, such as estates, country clubs and the like. The "Little Chief" may be employed with a pneumatic pressure tank or elevated tank, for full automatic operation. The new pumps contain all of the features of Pomona's "Big Chiefs" such as cutless water-lubricated bearings in the bowls; adjustable semi-open impellers, operating in cone shaped bowl seats; full-oating revolvable rubber shaft sleeves; stainless steel bearing contacts on the shaft; extra heavy column pipe, in 5 ft. lengths upwards. For Bul. No. 30 presenting the interesting "Little Chief," write Pomona Pump Co., Pomona, Calif., or St. Louis Mo.

"An Improved Laboratory Mixer," offered by Phipps and Bird, is described in a new catalog insert which points out the features of their improved varispeed mixer for laboratory tests and checking of coagulation efficiency and chemical economy. Some form of laboratory mixer is now considered almost essential in filter plant operation or chemical precipitation sewage treatment plants. For a copy, write Phipps and Bird, Inc., Richmond, Va.

"Modernity Overtakes Pool Filtration" — Such may be something of a shock, but it's all there in an International Filter Co. bulletin which, although it opens backwards, presents ideas that are very much forward. The feature of greatest interest, in "Infilco's" adaptation of modern practice and gravity filters in pool recirculation systems, is the mixing and flocculation chamber. It is equipped with rotating paddle to produce a *real* floc before filtration and not within the sand bed as chemical pot-fed pressure units frequently do. In addition each filter unit is open to visual inspection and surface cleaning of the bed, if required. Each unit has a two-way rate controller which precludes over rates both ways—in filtration and in back-washing. Noncorrodible filter underdrainage system of "Transite" is offered as optional. The brochure does not explain why the floc forming chamber (5 minutes period or more) is captioned the "Reception Basin," but from it there is no piping to shred the floc enroute to the filters. For Bul. 2010, write International Filter Co., 59 E. Van-Buren St., Chicago, Ill.

"Pottstown Blowers"—are described in a new folder from Pottstown Blower Company—long established manufacturers of rotary blowers. Distinctive features of Pottstown Oil-less Blowers are recounted. In the folder is a useful chart revealing blower performance in respect to power consumption for various air deliveries against various heads. The folder announces special engineering services in connection with problems involving possible application of blowers or compressors. For this folder and further details, write Pottstown Blower Co., Pottstown, Pa.

"Bellows Type Expansion Joints"—Are the subject of a special bulletin from the Foster Wheeler Corp., New York City. In it are described the packless Type "S" Expansion Joints, in which the flexible element consists of a bellows of stainless steel. The sliding parts within the joint require no lubrication and the feature is the extreme flexibility of the steel bellows, and the all-weld steel body construction, proven as to durability in service and in extreme shop tests for ultimate fatigue. These joints, supplied with flanged ends or welding nipples, are available in sizes from 2 to 36 inch in a standard series for presure up to 300 pounds and

Why is the Empire Meter *Measuring Chamber*

ACCURATE ON BOTH LARGE AND SMALL FLOWS?

For fifty-five years, the Empire Meter has been measuring flows both large and small with greater accuracy than any other meter ever manufactured . . .

because **of the use of the time-tested positive displacement principle . . . one that consists of the continuous filling and emptying of a cylinder as constant in volume as a tester's measure.**

because **of the balanced piston . . . one so perfectly balanced that the actuating pressures can move it only in its normal circular direction . . . with negligible friction and entirely without strain.**

. . . or, briefly, because of the sound principle of design . . . because it is easier for the water to push the piston ahead than it is to escape around it!

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NATIONAL *Meters*

Remember this . . . maximum accuracy on large and small flows + fewer stoppages and stickages + minimum maintenance = maximum water revenue.

Nice Going

for a pump that weighs only

91 POUNDS COMPLETE

One look at a Homelite in action and you'll say to yourself—"There's the pump for me." It pumps 15,000 gallons per hour. Handles sludge, slop, muddy water and 35% sand without clogging. Has a 28 foot suction lift. And features the fastest automatic self-priming—priming that keeps seepage, *in any amount,* constantly at strainer level.

All this pumping comes from a low-cost, compact unit that weighs only 91 pounds, complete with built-in gasoline engine. A pump that's easy to move around and get going without delays. A rugged, self-operating 3" pump that's built for years of hard-boiled service.

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FINEST TC QUALITY
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COPPER SULPHATE

99% *Purity*

In all sizes:

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CRYSTALS
for water treatment

- **SNOW**
- **POWDERED**

in barrels or 100-lb. bags

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ALSO

TENNESSEE FERRIC SULPHATE

Cold Water Soluble Ferric Iron for Water and Sewerage Treatment Plants

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Atlanta, Ga. **Lockland, Ohio**

temperatures up to 750 deg. F. They are especially adaptable to compresed air and steam lines, the manufacturer having a background of 40 years of manufacture of expansion joints. For a copy of bulletin X-39-5 write Foster Wheeler Corp., 165 Broadway, New York City, N. Y.

"Haymanite"—the jointing compound produced by Michael Hayman & Co., of Buffalo, is described in a new bulletin. Illustrated instructions for using "Haymanite" occupy two pages, and statements of satisfied users follow. Other materials supplied by Hayman, including caulking lead and braided hemp, are also presented. For a copy of "Positive Joints With Haymanite" write Michael Hayman & Company, 856 East Ferry St., Buffalo, New York.

"Flexible Pump Shafts" have proved their worth in the water works and sewerage fields. In a new catalog, Mechanics Universal Joint Div. of Borg-Warner Corp. describe and illustrate in detail the features of their Roller Bearing Joints and Flexible Drive Shafts. These non-rigid shafts do away with the misalignment bugaboo, insures smooth operation, and permits quick and easy disassembling and assembling of pump or drive unit. They are applicable for vertical or horizontal drive. In vertical drive sewage pumping, flexible shafting has given a particularly good account of itself, likewise for deep well turbines. The new bulletin also contains General Engineering Data of worth in planning flexible shaft drive. For a copy of "'Flexible Pump Shafts," write Mechanics Universal Joint Div., Borg-Warner Corp., Rockford, Ill.

"Deep Well Turbines" of the latest improved design are presented in a new bulletin from Worthington. Details of pump, shafting arrangement, water column and motor are covered in line drawings and close-ups of the distinctive features and improved design. For a copy of the Type QE Bulletin (-W-450-B 19 C) write Worthington Pump and Machinery Corp., Harrison, N. J.

"Self Priming Turbines"—are offered by Roots-Connersville (Turbine Pump Div.) in a recent form which describes the new horizontal turbines without stuffing boxes, no longer required because of the seals which rotate with the shaft. Designed especially as hard duty boiler-feed and condensate return pumps, which will not vapor bind or lose suction, these pumps likewise have other applications. They come completely furnished with all controls ready to connect in as a ready-to-serve unit. For Form B 14 - HB, write Roots-Connersville Corp., Connersville, Ind.

"Feed Water Control"—is the subject of a 16-page bulletin descriptive of Bailey Meter Co.'s "Three Element Feed Water Control." The three elements found in the system accurately measure (1) Feed Water—input to the boiler; (2) Steam—flows from the boiler; (3) Boiler Water Level—in the boiler. Automatically the combination functions to control feed water input to equal steam output at all times. The bulletin diagramatically illustrates the functioning of the system which operates on compressed air, and indicates and records the three conditions continuously. For Bul. No. 105 write Bailey Meter Co., 1050 Ivanhoe Road, Cleveland, Ohio.

Ferrisul proves efficient and economical sewage coagulant

After extensive tests, Ferrisul was chosen as the most economical and efficient coagulant for use in this plain sedimentation plant with separate sludge digestion.

Summer sewage treatment in a midwestern city of 25,000 population was a problem with many perplexing factors. The raw flow, varying from 2.4 to 8 million gallons daily, was mostly domestic sewage, but cannery, paper mill and dye wastes often changed the pH and chemical content of the flow from hour to hour. Raw suspended solids varied from 250 to 570 ppm; raw B. O. D. from 300 to 600 ppm.

Complex though the problem was, the use of Ferrisul as a coagulant solved it efficiently and economically. An exceedingly small dosage of 1.3 grains per gallon improved the average suspended solids removal 105 per cent and average B. O. D. removal 72 per cent. Odor and color from dye wastes were eliminated.

If you are dreading the summer because it means sewage treatment worries, solve your problems now by selecting the all-purpose, all-year coagulant — Ferrisul. Write today for details. MONSANTO CHEMICAL COMPANY, Merrimac Division, Everett Station, Boston, Mass.

FERRISUL FOR WASTE AND SEWAGE DISPOSAL

MONSANTO CHEMICALS
SERVING INDUSTRY . . . WHICH SERVES MANKIND

At the A. W. W. A. Convention Atlantic City June 11-15

SEE THE

UNIVERSAL CAST IRON PIPE EXHIBIT BOOTHS
No Bell Holes To Dig
No Pouring of Lead or Lead Substitutes
Laid with Just Wrenches

The Central Foundry Co.
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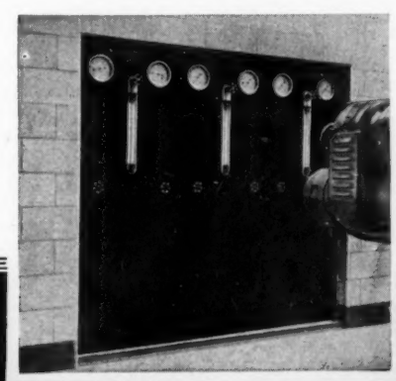

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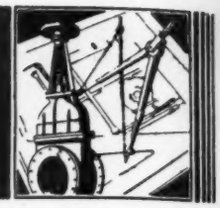

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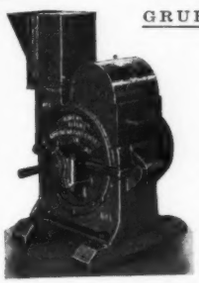

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1939

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The contents represent matter carefully selected from the files of WATER WORKS AND SEWERAGE and other sources named in the text. In addition, a considerable effort has been made to secure the latest hydraulic tables and standards, and to present the most economical and modern methods.

The same conscientious work has been put into the preparation of this Reference and Data Section (which is included in the regular* subscription charge) as would be expected in a book devoted exclusively to the same purposes.

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*NOTE—All *new* subscribers may have a copy of this special issue, so long as the supply lasts, and at no extra cost. Old subscribers will note that considerable material in this issue has appeared in earlier issues. The nature of this material is such that we find it difficult to replace. With the constant influx of new subscribers in mind, the most basic material is permanently retained, some new is added, some old is repeated in issues of alternate years, and some is permanently dropped.

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X-Y-Z

CLASSIFIED INDEX of PRODUCTS

Although this index is not published as a COMPLETE index of all materials and equipment used in the Water Works and Sewerage fields—it really is a very comprehensive list of products. It includes equipment and materials produced or marketed in this field by 146 manufacturers who have used WATER WORKS AND SEWERAGE in advertising such products during 1938 and 1939. Of these 146 manufacturers you will find the advertisements of 131 in this issue.

ABRASIVES

Carborundum Co., Niagara Falls, N. Y.

ACID, SULPHURIC AND HYDROCHLORIC

Dow Chemical Co., Midland, Mich
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
General Chemical Co., 40 Rector St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

ACTIVATED AND BLACK ALUM

Activated Alum Corp., Curtis Bay, Baltimore, Md.

ACTIVATED CARBON

American Water Softener Co., Lehigh and 4th Sts., Philadelphia, Pa.
Cliffs-Dow Chemical Co., Marquette, Mich.
Darco Corporation, 60 E. 42nd St., New York City.
Industrial Chemical Sales Division, West Virginia Pulp & Paper Co., 230 Park Ave., New York City.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
L. A. Salomon & Bro., 216 Pearl St., New York City.

ACTIVATED SLUDGE EQUIPMENT

American Well Works, Inc., Aurora, Ill.
Carborundum Co., Niagara Falls, N. Y.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Simplex Valve & Meter Co., Philadelphia, Pa.

AERATION APPARATUS

American Water Softener Co., Lehigh & 4th Sts., Philadelphia, Pa.
American Well Works, Inc., Aurora, Ill.
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Carborundum Co., Niagara Falls, N. Y.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 6Sth and Upland, Philadelphia, Pa.
Vogt Mfg. Co., Louisville, Ky.

AERO--FILTERS

Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.

AGITATORS

American Water Softener Co., Lehigh and 4th Sts., Philadelphia, Pa.

E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Chain Belt Co., Milwaukee, Wis.
Chicago Bridge & Iron Co., 2198 Old Colony Bldg., Chicago, Ill.
Dorr Co., Inc., 570 Lexington Ave., New York City.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Vogt Mfg. Co., Louisville, Ky.

AIR BLOWERS
(See Blowers, Air)

AIR COMPRESSORS
(See Compressors, Air)

AIR LIFT PUMPING SYSTEMS
Worthington Pump & Machy. Corp., Harrison, N. J.

AIR VALVES
(See Valves, Air)

ALLOY CAST IRON PIPE AND FITTINGS
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Lynchburg Foundry Co., Lynchburg, Va.
U. S. Pipe & Foundry Co., Burlington, N. J.

ALTERNATORS, ELECTRIC
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Clark Controller Co., 1146 E. 152nd St., Cleveland, O.

ALUM, AMMONIA
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

ALUM, BLACK
Activated Alum Corp., Curtis Bay, Baltimore, Md.

ALUM (FILTER), COMMERCIAL, IRON-FREE
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

AMMONIA, ANHYDROUS & AQUA
General Chemical Co., 40 Rector St., New York City.
Mathieson Alkali Wks., Inc., 60 E. 42nd St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

AMMONIATORS
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Pardee Engrg. Co., 3915 29th St,. Long Island City, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders Co., 110 Washington St., Buffalo, N. Y.

ANALYTICAL WARE
Carborundum Co., Niagara Falls, N. Y.

ANTHRAFILT
Hudson Coal Co., Scranton, Pa.

ASBESTOS-CEMENT PIPE
Asbestos-Cement Pipes, Inc., 225 Broadway, New York City.
Johns-Manville Co., 22 E. 40th St., New York City.

ASH AND COAL HANDLING MACHINERY
Chain Belt Co., Milwaukee, Wis.
Dracco Corp., Cleveland, Ohio.
Fuller Co., Catasauqua, Pa.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Koppers Rheolaveur Co., Pittsburgh, Pa.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

AUTOMATIC FILTER AND SOFTENER CONTROLS
American Water Softener Co., Lehigh & 4th Sts., Philadelphia, Pa.
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
International Filter Co., 50 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., Philadelphia, Pa.

BACK FILLERS
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

BAR SCREENS
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Filtration Equipment Corp., 10 E. 40th St., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

BASE-EXCHANGE SILICATE
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Philadelphia Quartz Co., Philadelphia, Pa.

BENTONITE
American Colloid Co., 363 W. Superior St., Chicago, Ill.

BINS, STORAGE
Chain Belt Co., Milwaukee, Wis.
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa

BITUMINOUS COATINGS AND LININGS
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Inertol Co., Inc., 401 Broadway, New York City.
Koppers Co., Tar & Chem. Div., Pittsburgh, Pa.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.

BLACK ALUM
Activated Alum Corp., Curtis Bay, Baltimore, Md.

BLEACHING POWDER
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

BLOWERS, AIR
Roots-Connersville Blower Corp., Connersville, Ind.

BLOWERS (GASOLINE ENGINE DRIVEN, PORTABLE)
Homelite Corporation, Port Chester, N. Y.

BOILER BLOWOFF APPARATUS
Permutit Co., 330 W. 42nd St., New York City.

BOILER FEED PUMP CONTROL
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland, Ohio.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

BOILER FEEDWATER TREATMENT
Activated Alum Corp., Curtis Bay, Baltimore, Md.
American Water Softener Co., Lehigh & 4th Sts., Philadelphia, Pa.
Buromin Co., 300 Ross St., Pittsburgh, Pa.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Hall Laboratories, Inc., 300 Ross St., Pittsburgh, Pa.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Permutit Co., 330 W. 42nd St., New York City.
Philadelphia Quartz Co., Philadelphia, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Penn.

BOILER FURNACE, BRICK
Carborundum Co., Niagara Falls, N. Y.

BOILER PLANT ACCESSORIES
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland, Ohio.
Hagan Corp., 300 Ross St., Pittsburgh, Pa.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
So. Bend Foundry Co., So. Bend, Ind.

BOILERS, GAS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.

BOILER WATER CONTROL EQUIPMENT (pH & PHOSPHATE)
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.

BOILER WATER PURIFICATION APPARATUS
American Water Softener Co., Lehigh & 4th Sts., Philadelphia, Pa.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.

BOOKS, TECHNICAL, SCIENTIFIC, BUSINESS
John Wiley & Sons, 440 4th Ave., New York City.

BORER—UNDERGROUND PIPE INSTALLATION
Hydrauger Corp., Ltd., 116 New Montgomery, San Francisco, Cal.

BOXES, VALVES AND METERS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
M. & H. Valve & Fittings Co., Anniston, Ala.
Modern Iron Works, Quincy, Ill.
Mueller Co., Decatur, Ill.
Rensselaer Valve Co., Troy, N. Y.
Road Supply & Metal Co., Topeka, Kan.
Trohn's Supplies, Inc., Mamaroneck, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.

BRAKES, MAGNETIC, MECHANICAL, HYDRAULIC
The Clark Controller Co., 1146 East 152nd St., Cleveland, Ohio.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

BRASS GOODS
(See also Pipe, Brass.)
American Brass Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago.
Farnan Brass Works Co., P. O. Box 6147, Cleveland, Ohio.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
Mueller Co., Decatur, Ill.
Trohn's Supplies, Inc., Mamaroneck, N. Y.

BREECHINGS, STEEL
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

BRICKS, ACID PROOF
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.

BUCKETS, DREDGING & EXCAVATING
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

BUCKETS, SEWER
Champion Corp., Hammond, Ind.
Eimco Corp., 634 So. Fourth West St., Salt Lake City, Utah.
Turbine Sewer Machine Co., 5210 W. State St., Milwaukee, Wis.

BUFFER SOLUTIONS & MIXTURES
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.

CALCIUM HYPOCHLORITE
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

CALKING MACHINES AND TOOLS
Mueller Co., Decatur, Ill.

CARBON-ACTIVATED
(See Activated Carbon.)

CARBONATORS (Recarbonation).
E. W. Bachrach & Co., Rialto Bldg., Kansas City, Mo.
Carborundum Co., Niagara Falls, N. Y.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

CASTINGS, IRON, STEEL, ALLOY STEEL, ETC.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Chain Belt Co., Milwaukee, Wis.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill. (Bronze).
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Lynchburg Foundry Co., Lynchburg, Va.
So. Bend Foundry Co., So. Bend, Ind.
U. S. Pipe & Foundry Co., Burlington, N. J.

CAST IRON PIPE
(See Pipe.)

CATCH BASINS, CORRUGATED IRON
Armco Culvert Mfrs. Assn., Middletown, Ohio.

CATHODIC PROTECTIVE PROCESS
Electro Rust-Proofing Co., 38 N. Jefferson St., Dayton, Ohio.

CAUSTIC SODA
The Columbia Alkali Corp., Barberton, Ohio.
Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich.
Electro - Bleaching Gas Co., 60 E. 42nd St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Great Western Electro - Chemical Co., Div. Dow Chemical Co., 9 Main St., San Francisco, Calif.
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Solvay Sales Corp., 40 Rector St., New York City.

CEMENT
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.

CEMENT, ASBESTOS PIPE
Johns-Manville, 22 E. 40th St., New York City.

CEMENT PIPE
(See Pipe, Cement; Pipe, Concrete.)

CEMENT LINED PIPE
(See Pipe.)

CEMENTS, ACID PROOF
Atlas Mineral Prod. Co., Mertztown, Pa.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Philadelphia Quartz Co., Philadelphia, Pa.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.

CEMENTS, REFRACTORY
Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.

CEMENTS, SEWER PIPE
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.

CEMENTS, WATER MAINS
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Leadite Co., Girard Trust Bldg., Philadelphia, Pa.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.

CHEMICAL CONVEYING EQUIPMENT
Chain Belt Co., Milwaukee, Wis.
Dracco Corp., Cleveland, Ohio.
Fuller Co., Catasauqua, Pa.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

CHEMICAL FEEDING & PROPORTIONING EQUIPMENT
American Water Softener Co., Lehigh Ave. and 4th St., Philadelphia, Pa.
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Builders Iron Foundry, 9 Codding St., Providence, R. I.
Calgon, Inc., 300 Ross St., Pittsburgh, Pa.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Syntron Co., Homer City, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeder, Inc., 110 Washington St., Buffalo, N. Y.

CHEMICALS FOR WATER PURIFICATION
Activated Alum Corp., Curtis Bay, Baltimore, Md.
American Colloid Co., 363 W. Superior St., Chicago, Ill.
Cliffs-Dow Chemical Co., Marquette, Mich.
The Columbia Alkali Corp., Barberton, Ohio.
Darco Corp., 60 E. 42nd St., New York City.
Diamond Alkali Co., Pittsburgh, Pa.
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., 230 Park Ave., New York.
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Works, Inc., 60 E. 42nd St., New York.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Monsanto Chemical Co., St. Louis, Mo.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
L. A. Salomon & Bro., 216 Pearl St., New York City.
Solvay Sales Corp., 40 Rector St., New York.

CHEMISTS AND ENGINEERS
(See Directory of Experts, pages 106, 107.)

CHLORIDE, FERRIC
Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich.
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Great Western Electro-Chemical Co., Div. Dow Chemical Co., 9 Main St., San Francisco, Calif.
Innis-Speiden & Co., 117 Liberty St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

CHLORIDE OF LIME (CHLORINATED LIME)
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

CHLORINATORS
(See also Hypochlorinators.)
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Pardee Engrg. Co., 3915 29th St., Long Island City, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan, Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

CHLORINE, LIQUID
The Columbia Alkali Corp., Barberton, Ohio.
Diamond Alkali Co., Pittsburgh, Pa.
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Great Western Electro-Chemical Co., Div. Dow Chemical Co., 9 Main St., San Francisco, Calif.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Monsanto Chem. Co., St. Louis, Mo.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Solvay Sales Corp., 40 Rector St., New York.
Wallace & Tiernan, Inc., Newark, N. J.

CHLORINE CONTROL EQUIPMENT
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.

CHUTES, COAL, ETC.
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Link Belt Co., 300 W. Pershing Rd., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

CLAMPS AND SLEEVES, PIPE
Amer. Cast Iron Pipe Co., Birmingham, Ala.
Carson-Cadillac Corp., Birmingham, Ala.
Dresser Mfg. Co., Bradford, Pa.

CLAMPS, BELL JOINT
Carson-Cadillac Corp., Birmingham, Ala.
Dresser Mfg. Co., Bradford, Pa.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

CLAMPS, PIPE REPAIR
Carson-Cadillac Corp., Birmingham, Ala.
Dresser Mfg. Co., Bradford, Pa.

CLARIFIERS, SEWERAGE AND WATER
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Permutit Co., 330 W. 42nd St., New York City.

CLEANING SEWER MAINS
Champion Corp., Hammond, Ind.
Turbine Sewer Machine Co., 5210 W. State St., Milwaukee, Wis.

CLEANING WATER MAINS
National Water Main Cleaning Co., 50 Church St., New York City.

COAGULANTS AND COAGULATION CONTROL CHEMICALS
Activated Alum Corp., Curtis Bay, Baltimore, Md.
American Colloid Co., 363 W. Superior St., Chicago, Ill.
Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Innis-Speiden & Co., 117 Liberty St., New York City.
Monsanto Chem. Co., Merrimac Div., Everett Station, Boston, Mass.
Monsanto Chemical Co., St. Louis, Mo.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Philadelphia Quartz Co., Philadelphia, Pa.
Wallace & Tiernan Co., Newark, N. J.

COAL & ASHES HANDLING MACHINERY
(See Ash & Coal Handling Machy.)

COAL ANTHRAFILT
Hudson Coal Co., Scranton, Pa.

COATINGS, ACID & ALKALI-PROOF FOR CONCRETE, STEEL AND WOOD
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Inertol Co., Inc., 401 Broadway, New York City.
Philadelphia Quartz Co., Philadelphia, Pa.
Tar & Chem. Div., Koppers Co., Pittsburgh, Pa.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.

COATINGS AND LININGS
(See Bituminous Coatings and Linings.)

COCKS, CURB, METER, CORPORATION, ETC.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Farnan Brass Works Co., P. O. Box 6147, Cleveland, Ohio.
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Trohn's Supplies, Inc., Mamaroneck, N. Y.

COLLECTORS (SLUDGE)
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Permutit Co., 330 W. 42nd St., New York City.

COLLOIDAL CLAY
American Colloid Co., 363 W. Superior St., Chicago, Ill.

COMBUSTION INDICATORS AND RECORDERS
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland, Ohio.
Permutit Co., 330 W. 42nd St., New York City.

COMMINUTORS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.

COMPARATORS (COLOR)
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.

COMPOUNDS, SEWER JOINT
Atlas Mineral Prod., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.

COMPRESSORS, AIR
De Laval Steam Turbine Co., Trenton, N. J.
Fuller Co., Catasauqua, Pa.
Worthington Pump & Machy. Corp., Harrison, N. J.

COMPRESSORS, PORTABLE
Worthington Pump & Mach. Corp., Harrison, N. J.

CONCRETE—ARCHITECTURAL DESIGN
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.

CONCRETE, COLORING COMPOUNDS
Master Builders Co., 7016 Euclid Ave., Cleveland, Ohio.

CONCRETE HARDENER
Master Builders Co., 7016 Euclid Ave., Cleveland, Ohio.
Philadelphia Quartz Co., Philadelphia, Pa.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.

CONCRETE MIXERS
Chain Belt Co., Milwaukee, Wis.

CONCRETE PIPE FORMS
Quinn Wire & Iron Works, Boone, Iowa.

CONCRETE PIPE
(See Pipe, Concrete.)

CONDENSERS (STEAM)
Amer. Cast Iron Pipe Co., Birmingham, Ala.
Lynchburg Foundry Co., Lynchburg, Va.
U. S. Pipe & Foundry Co., Burlington, N. J.
Worthington Pump & Machy. Corp., Harrison, N. J.

CONTROLLERS, AUTOMATIC, ELECTRIC
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

CONTROLLERS, FLOW, LEVEL, PRESSURE, RATIO, TEMPERATURE
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
Hagan Corp., 300 Ross St., Pittsburgh, Pa.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., Troy, N. Y.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.

CONVEYORS AND CONVEYING EQUIPMENT
Chain Belt Co., Milwaukee, Wis.
Dracco Corp., Cleveland, Ohio.
Eimco Corp., 634 So. Fourth West St., Salt Lake City, Utah.
Fuller Co., Catasauqua, Pa.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Koppers Co., Engrg. & Constr. Div., Pittsburgh, Pa.
Link-Belt Mfg. Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

COOLING TOWERS
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.

COPPER, BRASS, BRONZE
American Brass Co., Waterbury, Conn.

COPPERAS
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Innis-Speiden & Co., 117 Liberty St., New York City.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.

COPPER SULPHATE
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
General Chemical Co., 40 Rector St., New York City.
Innis-Speiden & Co., 117 Liberty St., New York City.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga.

COPPER TUBE, FLEXIBLE
American Brass Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Co., Decatur, Ill.

COUPLINGS AND CONNECTIONS, PIPE
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Farnan Brass Works Co., P. O. Box 6147, Cleveland, Ohio.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

COUPLINGS, FLEXIBLE
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Koppers Co., Bartlett Hayward Div., Baltimore, Md.
Link Belt Co., 220 S. Belmont Ave., Indianapolis, Ind.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

CRANES & HOISTS
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

CULVERTS
American Cast Iron Pipe Co., Birmingham, Ala.
Armco Culvert Mfrs. Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City (Asbestos-Cement).
Lock Joint Pipe Co., Ampere, N. J.
Lynchburg Foundry Co., Lynchburg, Va.
U. S. Pipe & Foundry Co., Burlington, N. J. (Cast Iron)
R. D. Wood Co., Philadelphia, Pa.

CURB BOXES
Farnan Brass Works Co., Cleveland, Ohio.
Mueller Co., Decatur, Ill.
Modern Iron Works, Quincy, Ill.
Trohn's Supplies, Inc., Mamaroneck, N. Y.

DECHLORINATORS
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Omega Machine Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Newark, N. J.

DIAPHRAGM, PUMP
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Edson Corp., 49 D St., South Boston, Mass.
Eimco Corp., 634 So. Fourth West St., Salt Lake City, Utah

DIFFUSERS—PLATES AND TUBES
Carborundum Co., Niagara Falls, N. Y.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

DIGESTERS EQUIPMENT (SLUDGE)
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

DISTRIBUTORS (FILTER)
American Well Works, Inc., Aurora, Ill.
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

DRAINS, STORM
Armco Culvert Mfrs. Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Lock Joint Pipe Co., Ampere, N. J.
R. D. Wood Co., Philadelphia, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.

DRILLS, ROCK
Worthington Pump & Mach. Corp., Harrison, N. J.

DRIVES, CHAIN
Chain Belt Co., Milwaukee, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

DRY CHEMICAL FEEDERS
(See Chemical Feeding Equipment)

DRYERS, ROTARY
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

ELECTRICALLY OPERATED GATE VALVES
Crane Co., 836 S. Michigan Ave., Chicago.
Koppers Co., Bartlett Hayward Div., Baltimore, Md.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.

ELEVATING AND CONVEYING EQUIPMENT
(See Conveyors & Conveying Equipment.)

ENGINEERS AND CHEMISTS
(See Directory of Experts, pages 106, 107.)

ENGINES, DIESEL
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Rathbun-Jones Engrg. Co., Toledo, Ohio.
Worthington Pump Corp., Harrison, N. J.

ENGINES, SEWAGE SLUDGE GAS
Rathbun-Jones Engrg. Co., Toledo, Ohio.
Worthington Pump & Machy. Corp., Harrison, N. J.

EXPANSION JOINTS—PIPE
(See Joints—Expansion, Pipe)

FEED, CHEMICAL
(See Chemical Feeding Equipment.)

FEED WATER FILTERS
American Water Softener Co., Lehigh Ave. and 4th St., Philadelphia, Pa.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., Troy, N. Y.

FEED WATER HEATERS
Permutit Co., 330 W. 42nd St., New York City.
Worthington Pump & Mach. Corp., Harrison, N. J.

FEED WATER TESTING OUTFITS
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.

FEED WATER TREATMENT
(See Boiler Feed Water Treatment)

FERRIC CHLORIDE, LIQUID AND ANHYDROUS
Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich. (Liquid)
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
General Chemical Co., 40 Rector St., New York City.
Great Western Electro-Chemical Co., Div. Dow Chemical Co., 9 Main St., San Francisco, Calif.
Innis, Speiden & Co., 117 Liberty St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa. (Liquid)

FERRIC SULFATE
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Monsanto Chem. Co., St. Louis, Mo.
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga.

FERROUS SULPHATE
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
General Chemical Co., 40 Rector St., New York City.
Innis, Speiden & Co., 117 Liberty St., New York City.

FILTER-AIDS
Johns-Manville, 22 E. 40th St., New York City. (Celite.)
L. A. Salomon & Bro., 216 Pearl St., New York City.
Wm. W. Stanley Co., Inc., 401 Broadway, New York City.

FILTER CLEANING PROCESS
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., 230 Park Ave., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

FILTER CLOTHS
(Cotton, Wool & Jute)
Wm. W. Stanley Co., Inc., 401 Broadway, New York City.

FILTER FABRICS, ACID-PROOF
Wm. W. Stanley Co., Inc., 401 Broadway, New York City.

FILTERING EQUIPMENT
American Water Softener Co., Lehigh & 4th St., Philadelphia, Pa.
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Chicago Bridge & Iron Co., 2198 Old Colony Bldg., Chicago, Ill.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Filtration Equipment Co., 10 E. 40th St., New York City.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Norwalk Tank Co., Inc., 1 No. Water St., So. Norwalk, Conn.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Roberts Filter Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

FILTER PLATES AND TUBES
Carborundum Co., Niagara Falls, N. Y.

FILTER RATE CONTROLLERS AND GAGES
(See Rate Controllers.)

FILTER AND WATER SOFTENING PLANTS (COMPLETE)
American Water Softener Co., Lehigh Ave. and 4th St., Philadelphia, Pa.
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Chicago Bridge & Iron Co., 2198 Old Colony Bldg., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Neville Island P. O., Pittsburgh, Pa.
Roberts Filter Mfg. Co., Darby, Pa.

FILTERS—MAGNETITE
Filtration Equipment Corp., 10 E. 40th St., New York City.

FILTERS, VACUUM
Eimco Corp., 634 So. Fourth West St., Salt Lake City, Utah.
Filtration Equipment Corp., 10 E. 40th St., New York City.
Oliver United Filters, Inc., 33 W. 42nd St., New York City.

FILTER UNDERDRAINS (PIPE & PLATES)
American Water Softener Co., Lehigh & 4th Sts., Philadelphia, Pa.
Armco Culvert Mfrs. Assn., Middletown, Ohio.
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Carborundum Co., Niagara Falls, N. Y.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

FILTER WASH CONTROL
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

FILTER SAND
(See also Anthrafilt.)
American Water Softener Co., Lehigh & 4th Sts., Philadelphia, Pa.
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Northern Gravel Co., P. O. Box 307, Muscatine, Iowa.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

FITTINGS, PIPE, SOLDER TYPE
American Brass Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Farnan Brass Works Co., P. O. Box 6147, Cleveland, Ohio.

FITTINGS, TEES, ELLS, ETC.
American Brass Co., Waterbury, Conn.
American Rolling Mill Co., Middletown, Ohio.
Builders Iron Foundry, 9 Coddington St., Providence, R. I.
Carson-Cadillac Corp., Birmingham, Ala.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Farnan Brass Works Co., Cleveland, Ohio.
Lynchburg Foundry Co., Lynchburg, Va.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Trohn's Supplies, Inc., Mamaroneck, N. Y.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

FLASH MIXING EQUIPMENT
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Chain Belt Co., Milwaukee, Wis.
Carborundum Co., Niagara Falls, N. Y.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

FLEXIBLE JOINTS
(See Joints, Flexible Pipe.)

FLOATING COVERS
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

FLOCCULATING EQUIPMENT
American Water Softener Co., Lehigh & 4th Sts., Philadelphia, Pa.
American Well Works, Inc., Aurora, Ill.
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.

Carborundum Co., Niagara Falls, N. Y.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Mfg. Co., Louisville, Ky.

FLOOR GRATING

Arrowhead Iron Wks., 421 W. 5th St., Kansas City, Mo.
Walter Bates Co., Inc., 208 S. La Salle St., Chicago, Ill.
William F. Klemp Co., 6601 S. Melvina Ave. (Clearing P. O. Station), Chicago, Ill.

FLOOR STANDS

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

FLOW RECORDERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry, 9 Codding St., Providence, R. I.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Simplex Valve & Meter Co., Philadelphia, Pa.
R. W. Sparling, 945 N. Main St., Los Angeles, Calif.

FLOW REGULATORS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Modern Iron Works, Quincy, Ill.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

FLUMES, IRON & STEEL

Armco Culvert Mfrs. Assn., Middletown, Ohio.
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

FOOT VALVE WITH STRAINER

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Edson Corp., 49 D St., So. Boston, Mass.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
R. D. Wood, Philadelphia, Pa.

FORMS & GASKETS FOR PIPE JOINTS

Dresser Mfg. Co., Bradford, Pa.
Johns-Manville, 22 E. 40th St., New York City.
L. A. Weston, Adams, Mass.

FURNACES, MELTING, POURING LADLES, POTS, ETC.

Atlas Mineral Products, Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., Decatur, Ill.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

GARBAGE DISPOSAL APPARATUS

Carborundum Co., Perth Amboy, N. J.
Chain Belt Co., Milwaukee, Wis.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Koppers Co., Engrg. & Constr. Div., Pittsburgh, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Nichols Engr. & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Underpinning & Foundation Co., 155 E. 44th St., New York City.

GAS DIFFUSERS

Carborundum Co., Niagara Falls, N. Y.
Dorr Co., 570 Lexington Ave., New York City.
Vogt Mfg. Co., Louisville, Ky.

GAS ENGINES

Worthington Pump & Mach. Corp., Harrison, N. J.

GAS HOLDERS

Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

GAS PUMPS

(See Pumps, Gas)

GAS PURIFICATION

(Equipment & Materials)
Connelly Iron Sponge & Governor Co., 3154 S. California Ave., Chicago, Ill.
Koppers Co., Pittsburgh, Pa.

GAS REGULATORS

(Pressure & Flow)
(See Regulators—Water & Gas)

GATES, SHEAR

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fitting Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.

GATES, SLUICE

Armco Culvert Mfrs. Assn., Middletown, Ohio.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.

GATE VALVE HOUSING

Ludlow Valve Mfg. Co., Troy, N. Y.
Rensselaer Valve Co., Troy, N. Y.

GATE VALVES

(See Valves, Gate.)

GAUGES (Liquid Level, Pressure Recording)

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry, 9 Codding St., Providence, R. I.
Connelly Iron Sponge & Governor Co., 3154 S. California Ave., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
R. W. Sparling, 945 N. Main St., Los Angeles, Calif.

GEARS, SPEED REDUCING

De Laval Steam Turbine Co., Trenton, N. J.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.

GENERATORS, SETS, ELECTRIC & DIESEL ENGINES

Homelite Corp., Port Chester, N. Y. (Gasoline Engine Driven and Portable.)
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
Worthington Pump Corp., Harrison, N. J.

GOOSENECKS

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Farnan Brass Works Co., P. O. Box 6147, Cleveland, Ohio.
Mueller Co., Decatur, Ill.
Trohn's Supplies, Inc., Mamaroneck, N. Y.

GRATINGS, FLOORINGS

Arrowhead Iron Wks., Kansas City, Mo.
Walter Bates Co., Inc., 208 S. La Salle St., Chicago, Ill.

GRAVEL—FOR FILTERS

Northern Gravel Co., P. O. Box 307, Muscatine, Iowa.

GREEN SAND (Zeolite)

International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

GRINDERS

Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.

GRIT CHAMBER EQUIPMENT

Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

HEATERS, FEED WATER

Worthington Pump & Machy. Corp., Harrison, N. J.

HOSE, STEAM, AIR, WATER, SUCTION

American Brass Co., Waterbury, Conn.
Edson Corp., 49 D St., So. Boston, Mass.

HYDRANT PROTECTORS

Edson Corp., 49 D. St., So. Boston, Mass.

HYDRANT PUMPS

(See Pumps, Hydrant.)

HYDRANTS (FIRE)

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Decatur, Ill.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

HYDRAULICALLY OPERATED GATE VALVES

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.

HYDROGEN ION EQUIPMENT

Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Permutit Co., 330 W. 42nd St., New York City.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.

HYPO-CHLORINATORS

American Water Softener Co., Lehigh & 4th St., Philadelphia, Pa.
E. W. Bachrach & Co., Rialto Bldg., Kansas City, Mo.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Pardee Engrg. Co., 3915 29th St., Long Island City, N. Y.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

HYPOCHLORITES (High Test)

(See Calcium Hypochlorite)

INCINERATORS

Dorr Co., Inc., 570 Lexington Ave., New York City.
Koppers Co., Engrg. & Constr. Div., Pittsburgh, Pa.
Nichols Engr., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Underpinning & Foundation Co., 155 E. 44th St., New York City.

INDICATOR POSTS

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
R. D. Wood Co., Philadelphia, Pa.

INDICATORS, LARGE DIAL, ILLUMINATED

Builders Iron Foundry, 9 Codding St., Providence, R. I.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

INSULATION

Carborundum Co., Perth Amboy, N. J.
Ford Meter Box Co., Wabash, Ind. (Water Meter).
Johns-Manville, 22 E. 40th St., New York City.

IRON SULPHATE

Innis, Speiden & Co., 117 Liberty St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.

JOINTING COMPOUND

Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Leadite Co., Philadelphia, Pa.
Mueller Co., Decatur, Ill.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.

JOINTS, EXPANSION—PIPE

Amer. Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Corp., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Lock-Joint Pipe Co., Ampere, N. J.
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.

JOINTS, FILLER

Inertol Co., 401 Broadway, New York City.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.

JOINTS, FLEXIBLE PIPE

American Cast Iron Pipe Co., Birmingham, Ala.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.

JOINTS, MECHANICAL (FLEXIBLE)

American Cast Iron Pipe Co., Birmingham, Ala.
Carson-Cadillac Corp., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Lynchburg Foundry Co., Lynchburg, Va.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Weston's Gaskets & Forms, Adams, Mass.
R. D. Wood Co., Philadelphia, Pa.

JUTE, BRAIDED AND TWISTED

Atlas Mineral Prod. Co., Mertztown, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hydraulic Development Corp., 50 Church St., New York City.
Johns-Manville, 22 E. 40th St., New York City.
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.

LABORATORY APPARATUS
Carborundum Co., Niagara Falls, N. Y.
Corning Glass Works, Corning, N. Y.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Wallace & Tiernan, Inc., Newark, N. J.
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.

LEADITE
The Leadite Co., Girard Trust Co. Bldg., Philadelphia, Pa.

LEAK LOCATING INSTRUMENTS
(See Water Leak Locating Instruments)

LIQUID CHLORINE
(See Chlorine, Liquid.)

MANOMETERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
Connelly Iron Sponge & Governor Co., 3154 S. California Ave., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

METER ACCESSORIES, BOXES, HOUSING, ETC.
Badger Meter Co., Milwaukee, Wis.
F. S. Brainard & Co., 246 Palm St., Hartford, Conn.
Ford Meter Box Co., Wabash, Ind.
Modern Iron Works, Quincy, Ill.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

METER COUPLINGS & YOKES
Badger Meter Mfg. Co., Milwaukee, Wisc.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
Neptune Meter Co., 50 West 50th St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

"METER-MASTERS"
(See Rate of Flow Recorders)

METERS, GAS
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Roots-Connersville Blower Corp., Connersville, Ind.

METERS, PITOT
Pitometer Co., 50 Church St., New York City.
Simplex Valve & Meter Co., 68th & Upham Sts., Philadelphia, Pa.

METER TESTING EQUIPMENT
Badger Meter Mfg. Co., Milwaukee, Wis.
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
National Meter Co., 4221 First Ave., Brooklyn, N. Y.
Neptune Meter Co., 50 W. 50th St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

METERS, VENTURI
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

METERS, WATER AND SEWAGE
Badger Meter Mfg. Co., Milwaukee, Wis.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron & Foundry Co., Providence, R. I.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
National Meter Co., 4221 First Ave., Brooklyn, N. Y.
Neptune Meter Co., 50 W. 50th St., New York City.
Northrop & Co., Inc., 50 Church St., New York City.
Phoenix Meter Corp., Prince Bay, Staten Island, New York.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
R. W. Sparling, 945 N. Main St., Los Angeles, Calif.
Worthington-Gamon Meter Co., Harrison, N. J.

METER WASHERS
Mabbs Hydraulic Packing Co., 431 S. Dearborn St., Chicago, Ill.

MIXERS, CHEMICAL
American Water Softener Co., Lehigh and 4th Sts., Philadelphia, Pa.
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Mfg. Co., Louisville, Ky.

MIXERS, CONCRETE
(See Concrete Mixers)

MIXING EQUIPMENT
(Water & Sewage)
Eimco Corp., 634 S. Fourth West St., Salt Lake City, Utah.

MOTOR STARTERS
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

NIPPLES, PIPE
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.

NOZZLES, FLOW
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Chain Belt Co., Milwaukee, Wis.
Pacific Flush Tank Co., 4241 N. Ravenswood Ave., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

NOZZLES, SPRAY
Chain Belt Co., Milwaukee, Wis.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

ODOR & CARBON EVALUATION AIDS
Darco Corp., 60 E. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
L. A. Salomon & Bro., 216 Pearl St., New York City.

OPERATING TABLES
American Water Softener Co., Lehigh and 4th Sts., Philadelphia, Pa.
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

ORIFICES
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

PACKING
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City.

PACKING, RAWHIDE
Mabbs Hydraulic Packing Co., 431 S. Dearborn St., Chicago, Ill.

PAINT, ACID RESISTING
Atlas Mineral Prod. Co., Mertztown, Pa.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Inertol Co., Inc., 401 Broadway, New York City.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh, Pa. (15)

PAVEMENT BREAKERS
Worthington Pump & Mach. Corp., Harrison, N. J.

PENSTOCKS
Chicago Bridge & Iron Co., 2198 Old Colony Bldg., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

PILING, CORRUGATED STEEL SHEET
Corrugated Steel Sheet Piling Corp., 228 N. La Salle St., Chicago, Ill.
Ingot Iron Railway Prod. Co., Middletown, Ohio.

PIPE, ACID PROOF
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Corning Glass Works, Corning, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Lynchburg Foundry Co., Lynchburg, Va.
U. S. Pipe & Foundry Co., Burlington, N. J.

PIPE AND TANK COATINGS
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Inertol Co., Inc., 401 Broadway, New York City.
Koppers Co., Tar & Chemical Div., Pittsburgh, Pa.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.

PIPE, ASBESTOS-CEMENT
Asbestos-Cement Pipes, Inc., 225 Broadway, New York City.
Johns-Manville Co., 22 E. 40th St., New York City.

PIPE, BRASS AND COPPER
American Brass Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.

PIPE, CAST IRON
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 4th Ave., New York City.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Lynchburg Foundry Co., Lynchburg Va.
U. S. Pipe & Foundry Co., Burlington, N. J.
R. D. Wood Co., Philadelphia, Pa.

PIPE, CAST IRON SERVICE
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.

PIPE, CEMENT LINED
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Lynchburg Foundry Co., Lynchburg, Va.
United States Pipe & Foundry Co., Burlington, N. J.
R. D. Wood Co., Philadelphia, Pa.

PIPE, CONCRETE, PRESSURE
Lockjoint Pipe Co., Ampere, N. J.
Portland Cement Association, 33 W. Grand Ave., Chicago, Ill.

PIPE, COPPER
American Brass Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Farnan Brass Works Co., P. O. Box 6147, Cleveland, Ohio.
Mueller Co., Decatur, Ill.

PIPE, CORRUGATED
Armco Culvert Mfrs. Assn., Middletown, Ohio.

PIPE, CULVERT
Armco Culvert Mfrs. Assn., Middletown, Ohio.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., Ampere, N. J.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.

PIPE CUTTING MACHINES
Crane Co., 836 S. Michigan Ave., Chicago, Ill.

PIPE ENAMELS, PROTECTIVE—COAL TAR
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Koppers Co., Tar & Chem. Div., Pittsburgh, Pa.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.

PIPE, FELT WRAPPING
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.

PIPE FITTINGS
American Cast Iron Pipe Co., Birmingham, Ala.
American Rolling Mill Co., Middletown, Ohio.
Carson-Cadillac Corp., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Lynchburg Foundry Co., Lynchburg, Va.
M. & H. Valve & Fitting Co., Anniston, Ala.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.
R. D. Wood Co., Philadelphia, Pa.

PIPE, GLASS
Corning Glass Works, Corning, N.Y.

PIPE JOINT COMPOUNDS
Atlas Mineral Products, Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Leadite Co., Philadelphia, Pa.
Master Builders Co., 7016 Euclid Ave., Cleveland, Ohio.
Modern Iron Works, Quincy, Ill.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh, Pa. (15)
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.

PIPE JOINTS, MECHANICAL
Carson-Cadillac Corp., Birmingham, Ala.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

PIPE JOINT TOOLS
Allan J. Coleman, 120 W. Illinois St., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., Decatur, Ill.
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.

PIPE, LEAD LINED
Crane Co., 836 S. Michigan Ave., Chicago, Ill.

PIPE LOCATORS
Water Leak Detector Co., 166 N. Third St., Columbus, Ohio.

PIPE, SEWER
American Cast Iron Pipe Co., Birmingham, Ala.
Armco Culvert Mfrs. Assn., Middletown, Ohio.
Cast Iron Pipe Research Corp., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., Ampere, N. J.

Lynchburg Foundry Co., Lynchburg, Va.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill. (Reinforced Concrete)
U. S. Pipe & Foundry Co., Burlington, N. J.

PIPE, STEEL
American Rolling Mill Co., Middletown, Ohio.
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

PIPE, SUBAQUEOUS
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Lock Joint Pipe Co., Ampere, N. J.

PIPE TAPPING MACHINES
Mueller Co., Decatur, Ill.

PIPE, WELDED STEEL
American Rolling Mill Co., Middletown, Ohio.
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

PIPE, WRAPPING
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.

PITOT TUBES
Builders Iron Foundry Co., Providence, R. I.
Pitometer Company, 50 Church St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

PNEUMATIC CONVEYORS FOR WATER AND SEWAGE TREATMENT
Dracco Corp., Cleveland, Ohio.
Fuller Co., Catasauqua, Pa.

POROUS TUBES AND PLATES
Carborundum Co., Niagara Falls, N. Y.

POTENTIOMETERS
Heilige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.

POURING GATES
Allan J. Coleman, 120 W. Illinois St., Chicago, Ill.

PRESSURE REGULATORS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Co., Decatur, Ill.
Ross Valve Mfg. Co., Troy, N. Y.

PROPORTIONING EQUIPMENT (CHEMICAL)
American Water Softener Co., Lehigh and 4th Sts., Philadelphia, Pa.
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Syntron Company, Homer City, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

PUMP MOTOR STARTERS
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.

PUMP PRIMERS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.

PUMPS, ACID-HANDLING
American Well Works, Aurora, Ill.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Oliver United Filters, Inc., 33 W. 42nd St., New York City (chemical).
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, AIR LIFT
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, BOILER FEED
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, CELLAR DRAINER
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, CENTRIFUGAL
American Well Works, Inc., Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Homelite Corp., Port Chester, N. Y.
Layne & Bowler, Inc., Memphis, Tenn.
Oliver United Filters, Inc., 33 W. 42nd St., New York City.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, CONDENSATION
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, DEEP WELL
American Well Works, Inc., Aurora, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Layne & Bowler, Inc., Memphis, Tenn.
Pomona Pump Co., Pomona, Calif.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, DIAPHRAGM
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Edson Corp., 49 D St., South Boston, Mass.
Eimco Corp., 634 S. Fourth West St., Salt Lake City, Utah.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Wallace & Tiernan Co., Inc., Newark, N. J.

PUMPS, DRAINAGE
American Well Works, Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Pomona Pump Co., Pomona, Calif.
S. Morgan Smith Co., York, Pa.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, GAS
(For CO_2 and Other Gases)
Roots - Connersville Blower Corp., Connersville, Ind.

PUMPS, HYDRAULIC
Ross Valve Mfg. Co., Troy, N. Y.

PUMPS, HYDRANT
Edson Corp., 49 D St., South Boston, Mass.

PUMPS, PORTABLE
Chain Belt Co., Milwaukee, Wis.
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 So. Michigan Ave., Chicago, Ill.
Homelite Corp., Port Chester, N. Y.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, PRIMING
Roots - Connersville Blower Corp., Connersville, Ind.

PUMPS, ROTARY
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Roots - Connersville Blower Corp., Connersville, Ind.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, SELF PRIMING
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Homelite Corp., Port Chester, N. Y.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, SEWAGE
American Well Works, Inc., Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Dorr Co., 570 Lexington Ave., New York City.
Eimco Corp., 634 S. Fourth West St., Salt Lake City, Utah.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, SLUDGE
American Well Works, Inc., Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Eimco Corp., 634 S. Fourth West St., Salt Lake City, Utah.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, SUCTION AND FORCE
Allan J. Coleman, 120 W. Illinois St., Chicago, Ill.
Edson Corp., 49 D St., South Boston, Mass.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, SUMP
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Pomona Pump Co., Pomona, Calif.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, TURBINE
American Well Works, Inc., Aurora, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Layne & Bowler, Inc., Memphis, Tenn.
Pomona Pump Co., Pomona, Calif.
Roots - Connersville Blower Corp., Connersville, Ind.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, VACUUM
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Eimco Corp., 634 S. Fourth West St., Salt Lake City, Utah.
Fuller Co., Catasauqua, Pa.
Oliver United Filters, Inc., 33 W. 42nd St., New York City.
Roots - Connersville Blower Corp., Connersville, Ind.
Vogt Brothers Mfg. Co., Louisville, Ky.
Worthington Pump & Machy. Corp., Harrison, N. J.

RATE OF FLOW CONTROLLERS
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

RATE OF FLOW RECORDERS
F. S. Brainard & Co., 246 Palm St., Hartford, Conn.
Neptune Meter Co., 50 W. 50th St., New York City.

REAMERS
Mueller Co., Decatur, Ill.

RECARBONATORS
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

RECORDING INSTRUMENTS
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland, Ohio.
F. S. Brainard & Co., 246 Palm St., Hartford, Conn.
Builders Iron Foundry, 9 Coddington St., Providence, R. I.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

RECUPERATOR
Carborundum Co., Perth Amboy, N. J.

REFRACTORIES
Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.

REGULATORS, SEWER
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

REGULATORS (Pressure), WATER AND GAS
Connelly Iron Sponge & Governor Co., 3154 S. California Ave., Chicago, Ill.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Ross Valve Mfg. Co., Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

RESERVOIRS
(See Standpipes and Tanks)

RINGS, ANTI-ROOT
A-B-C Manufacturing Co., Quincy, Ill.

ROBOT FILTER AND SOFTENER OPERATORS
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

RUST PREVENTION
(Tanks, Pipe Lines, Submerged Metal)
Electro Rust-Proofing Co., 38 N. Jefferson St., Dayton, Ohio (Cathodic Protection)
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Inertol Co., Inc., 401 Broadway, New York City.
Koppers Co., Tar & Chemical Div., Pittsburgh, Pa.
Philadelphia Quartz Co., Philadelphia, Pa.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.

SADDLES, PIPE
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Mueller Co., Decatur, Ill.

SAMPLERS AND SAMPLING TABLES

American Water Softener Co., Lehigh and 4th Sts., Philadelphia, Pa.
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
R. W. Sparling, 945 N. Main St., Los Angeles, Calif.

SAND EXPANSION INDICATORS

International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

SAND—FOR FILTERS

Northern Gravel Co., P. O. Box 307, Muscatine, Iowa.

SCREENS, INTAKE

Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

SCREENS, SAND, GRAVEL AND STONE

Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

SCREENS, SEWAGE

American Well Works, Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Filtration Equipment Corp., 10 E. 40th St., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

SCREENS, WATER WELL

Layne & Bowler, Inc., Memphis, Tenn.

SERVICE BOXES

Central Foundry Co., 386 Fourth Ave., New York City.

SEWAGE EJECTORS

Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.

SEWAGE SAMPLERS

Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

SEWAGE SCREENING GRINDERS

Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Royer Foundry & Mach. Co., Kingston, Pa.

SEWAGE SLUDGE INCINERATOR

Dorr Co., 570 Lexington Ave., New York City.
Nichols Engineering & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Underpinning & Foundation Co., 155 E. 44th St., New York City.

SEWER CLEANERS

Allan J. Coleman, 120 W. Illinois St., Chicago, Ill.
Champion Corp., Hammond, Ind.
Petersen Hydraulic Flusher Co., 617 S. Sixth St., Milwaukee, Wis.
Turbine Sewer Machine Co., 5210 W. State St., Milwaukee, Wis.

SEWER DESIGN—CONCRETE

(Literature, Information, Advice)
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.

SEWER PIPE

(See Pipe, Sewer)

SEWER PIPE JOINTS

A-B-C Manufacturing Co., Quincy, Ill. (Root Proof)
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.
L. A. Weston, Adams, Mass.

SEWER RODS

Champion Corp., Hammond, Ind.
Allan J. Coleman, 120 W. Illinois St., Chicago, Ill.
Turbine Sewer Machine Co., 5210 W. State St., Milwaukee, Wis.

SIGHT GLASSES

Corning Glass Works, Corning, N. Y. (Pyrex Brand)

SIGNALS, BIN

Fuller Co., Catasauqua, Pa.

SIPHONS (SEWAGE)

Armco Culvert Mfrs. Assoc., Middletown, Ohio.
Ralph B. Carter Co., 53 Park Place, New York City. (Alternating.)
Modern Iron Works, Quincy, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

SLEEVES, PIPE REPAIR

Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
M. & H. Valve & Fittings Co., Anniston, Pa.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

SLEEVES, TAPPING (VALVE)

Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.

SLUDGE COLLECTORS

American Well Works, Inc., Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Filtration Equipment Corp., 10 E. 40th St., New York City.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

SLUDGE DEWATERING

Eimco Corp., 634 S. Fourth West St., Salt Lake City, Utah.
Filtration Equipment Corp., 10 E. 40th St., New York City.

SLUDGE DISINTEGRATORS

Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Oliver United Filters, Inc., 33 W. 42nd St., New York City.
Royer Foundry & Mach. Co., 158 Pringle St., Kingston, Pa.

SLUDGE FILTERS (VACUUM)

Eimco Corp., 634 S. Fourth West St., Salt Lake City, Utah.
Filtration Equipment Corp., 10 E. 40th St., New York City.
Oliver United Filters Co., 33 W. 42nd St., New York City.

SLUDGE GAS PURIFIERS

Koppers Co., Bartlett - Hayward Div., Baltimore, Md.

SLUDGE INCINERATORS

(See Sewage Sludge Incinerators)

SLUDGE PUMPS

American Well Works, Inc., Aurora, Ill.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Eimco Corp., 634 S. Fourth West St., Salt Lake City, Utah.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

SODA ASH

The Columbia Alkali Corp., Barberton, Ohio.
Diamond Alkali Co., Pittsburgh, Pa.
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Innis, Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Works, 60 E. 42nd St., New York City.
Penn. Salt. Mfg. Co., Widener Bldg., Philadelphia, Pa.
Solvay Sales Corp., 40 Rector St., New York City.

SODIUM ALUMINATE

Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

SODIUM SILICATE

Diamond Alkali Co., Pittsburgh, Pa.
General Chemical Co., 40 Rector St., New York City.
Philadelphia Quartz Co., Philadelphia, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Standard Silicate Division, Diamond Alkali Co., Pittsburgh, Pa.

SOFTENERS AND PURIFIERS

American Water Softener Co., Lehigh Ave. at 4th St., Philadelphia, Pa.
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

SPEED REDUCERS, TRANSMISSION

De Laval Steam Turbine Co., Trenton, N. J.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Worthington Pump & Machy. Corp., Harrison, N. J.

SPRINKLING FILTER PLANTS

Dorr Co., 570 Lexington Ave., New York City.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

STACKS

Chicago Bridge & Iron Co., 2198 Old Colony Bldg., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

STACKS, FUME

Johns-Manville, 22 E. 40th St., New York City.

STANDPIPE AND TANKS

Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Norwalk Tank Co., Inc., 1 No. Water St., So. Norwalk, Conn.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

STANDPIPE PRESERVATION

(Cathodic Protection Process)
Electro Rust-Proofing Co., 38 N. Jefferson St., Dayton, Ohio.

STIRRERS (LABORATORY)

Dorr Co., 570 Lexington Ave., New York City.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.

STOKERS

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Link-Belt Co., 2410 W. 18th St., Chicago, Ill.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

STORAGE TANKS

Chicago Bridge & Iron Co., 2198 Old Colony Bldg., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Norwalk Tank Co., Inc., 1 No. Water St., So. Norwalk, Conn.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

STRAINERS, SUCTION

Edson Corp., 49 D St., South Boston, Mass.

SULPHATE OF ALUMINA

Activated Alum Corp., Curtis Bay, Baltimore, Md.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
General Chemical Co., 40 Rector St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.

SULPHER REMOVAL

(See Gas Purification)

SWIMMING POOL EQUIPMENT

American Water Softener Co., Lehigh and 4th Sts., Philadelphia, Pa.
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Co., Darby, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

SWIMMING POOL TESTING OUTFITS (pH and Chlorine)

Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.

SWITCHES, FLOAT, TRANSFER AND REMOTE CONTROL

Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.

TANKS, ELEVATED STEEL

Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Norwalk Tank Co., Inc., 1 No. Water St., So. Norwalk, Conn.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

TANK PRESERVATION

(Cathodic Protection Process)
Electro Rust-Proofing Co., 38 N. Jefferson St., Dayton, Ohio.

TANKS, RUBBER LINED

Wallace & Tiernan Co., Inc., Newark, N. J.

TANKS, STEEL

(See Tanks, Elevated Steel)

TAPPING MACHINES

Mueller Co., Decatur, Ill.

TASTE & ODOR CONTROL GRAPHS

Darco Corp., 60 E. 42nd St., New York City.

TASTE & ODOR REMOVAL CHEMICALS

Activated Alum Corp., Curtis Bay, Baltimore, Md.
American Colloid Co., 363 W. Superior St., Chicago, Ill.
Darco Corp., 60 E. 42nd St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., Inc., 230 Park Ave., New York City.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
L. A. Salomon & Bro., 216 Pearl St., New York City.
Wallace & Tiernan Co., Inc., Newark, N. J.

TESTERS, WATER METER

Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
National Meter Co., 4221 First Ave., Brooklyn, N. Y.
Neptune Meter Co., 50 W. 50th St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

THICKENERS
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.

TREADS, SAFETY
Arrowhead Iron Works, Kansas City, Mo.

TRITURATORS
(See also Grinders)
Chain Belt Co., Milwaukee, Wis.

TUNNEL MACHINERY, BORING & LINING
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

TURBINES, HYDRAULIC
De Laval Steam Turbine Co., Trenton, N. J.
S. Morgan Smith Co., York, Pa.

TURBINES, STEAM
De Laval Steam Turbine Co., Trenton, N. J.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.

VALVE BOXES
Central Foundry Co., 386 Fourth Ave, New York City.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ford Meter Box Co., Wabash, Ind.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Modern Iron Works, Quincy, Ill.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
Trohn's Supplies, Inc., Mamaroneck, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVES
Armco Culvert Mfrs. Assn., Middletown, Ohio.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fitting Co., Anniston, Ala.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.
Vogt Bros. Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVES, AIR RELEASE
Calif. Corrugated Culvert Co., Berkeley, Calif.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, AIR & VACUUM
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. D. Wood Co., 400 Chestnut St., Chicago, Ill.

VALVES, ALTITUDE
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Ross Valve Mfg. Co., Troy, N. Y.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.

VALVES, CHECK
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Connelly Iron Sponge & Governor Co., 3154 S. California Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rennselaer Valve Co., Troy, N. Y.
S. Morgan Smith Co., York, Pa.
R. D. Wood Co., Philadelphia, Pa.

VALVES, CHLORINE
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Wallace & Tiernan Co., Inc., Newark, N. J.

VALVES, CONE, OF ALL TYPES
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
S. Morgan Smith Co., York, Pa.

VALVES, EMERGENCY TRIP
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.

VALVES, FLAP
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, FLOAT
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Ludlow Valve Mfg. Co., Troy, N. Y.
Ross Valve Mfg. Co., Troy, N. Y.

VALVES, FOOT
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Edson Corp., 49 D St., South Boston, Mass.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, FOUR WAY
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Roberts Filter Mfg. Co., Darby, Pa.

VALVES, GATE
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Bartlett-Hayward Div., Koppers Co., Pittsburgh, Pa.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rennselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVES, HYDRAULIC CYLINDER OPERATED
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rennselaer Valve Co., Troy, N. Y.
S. Morgan Smith Co., York, Pa.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, MOTOR OPERATED
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Ludlow Valve Mfg. Co., Troy, N. Y.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
S. Morgan Smith Co., York, Pa.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, MUD AND PLUG
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Vogt Brothers Mfg. Co., Louisville, Ky.

VALVES, PRESSURE REDUCING
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Mueller Co., Decatur, Ill.
S. Morgan Smith, York, Pa.

VALVES, RELIEF
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Decatur, Ill.
Ross Valve Mfg. Co., Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, RUBBER, GLASS AND LEAD LINED
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.

VALVES, SPECIAL AUTOMATIC
Crane Co., 836 S. Michigan Ave., Chicago, Ill
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Ross Valve Mfg. Co., Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, WATER METER SPECIAL
Ford Meter Box Co., Wabash, Ind.

VARIABLE SPEED TRANSMISSIONS
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

VENTURI TUBES
Bailey Meter Co., 1072 Ivanhoe, Cleveland, Ohio.
Builders Iron Foundry, 9 Codding St., Providence, R. I.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia.

VIBRATORS, CONCRETE
Syntron Company, Homer City, Pa. Pa.

VIBRATORS, ELECTRO-MAGNETIC
Jeffrey Mfg. Co., Columbus, Ohio.
Syntron Company, Homer City, Pa.

WASTE GAS BURNERS
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

WATER ANALYSIS EQUIPMENT AND REAGENTS
Corning Glass Wks., Corning, N. Y.
Heilige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.

WATER LEAK, LOCATING INSTRUMENTS
Pitometer Co., 50 Church St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Water Leak Detector Co., 166 N. Third St., Columbus, Ohio.

WATER LEVEL RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

WATER MAIN CLEANING
National Water Main Cleaning Co., 50 Church St., New York City.

WATERPROOF CANVAS
Wm. W. Stanley Co., Inc., 401 Broadway, New York City.

WATERPROOFING PAINTS, COMPOUNDS AND MATERIALS
Connelly Iron Sponge & Governor Co., 3154 S. California Ave., Chicago, Ill.
General Paint Corp., Cleveland, Ohio.
Inertol Co., Inc., 401 Broadway, New York City.
Johns-Manville, 22 E. 40th St., New York City.
Koppers Co., Tar & Chem. Div., Pittsburgh, Pa.
Master Builders Co., 7016 Euclid Ave., Cleveland, Ohio.
Reilly Tar & Chem Co., Merchants Bank Bldg., Indianapolis, Ind.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.

WATER SOFTENERS
American Water Softener Co., Lehigh and 4th Sts., Philadelphia, Pa.
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Calgon, Inc., 300 Ross Ave., Pittsburgh, Pa.
International Filter Co., 59 E. Van Buren St., Chicago (lime-soda).
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit, Inc., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Co., Darby, Pa.

WATER WASTE SURVEYS
Pitometer Co., 50 Church St., New York City.

WEATHERPROOF PAINTS, ROOF COATINGS
General Paint Corp., 3091 Mayfield Road, Cleveland, Ohio.
Inertol Co., 401 Broadway, New York City.
Johns-Manville, 22 E. 40th St., New York City.
Tar & Chem. Div., Koppers Co., Pittsburgh, Pa.
Master Builders Co., 7016 Euclid Ave., Cleveland, Ohio.
Reilly Tar & Chem. Co., Merchants Bank Bldg., Indianapolis, Ind.

WEIGH FEEDER MACHINES
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Omega Machine Co., 4010 Penn Ave., Kansas City, Mo.

WELL WATER SUPPLY SYSTEMS
American Well Works, Aurora, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Layne & Bowler, Inc., Memphis, Tenn.

WRAPPING, PIPE
(See Pipe, Wrapping)

ZEOLITE AND ZEOLITE SOFTENERS
American Water Softener Co., Lehigh and 4th Sts., Philadelphia, Pa.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

PART I. WATER

FLOW, FRICTION, MEASUREMENT AND POWER*

The rate of flow or the volume of water passing a cross section of a stream in a unit time is called the "discharge." If a uniform velocity at all points in the cross section of a stream were possible, there would be passing any cross section of the stream, every unit of time, a prism of water having a base equal to the cross-sectional area of the stream and a length equal to the velocity. However, due to the varying effects of friction and viscosity, the different filaments of water move with different velocities. For this reason it is common in hydraulics to deal with "mean velocities."

The discharge may be expressed in terms of the mean velocity:

$$Q = av$$

where Q = Discharge in cubic feet per second.
a = Cross-sectional area of stream in square feet.
v = Mean velocity in feet per second.

When the discharge is constant (i.e., when the same quantity of water passes any cross section of a stream during equal successive intervals of time) the flow is said to be "steady."

Flow is said to be "uniform" when there is little or no change in the cross section or velocity from point to point in a stream.

Thus uniform flow implies similarity of conditions at successive cross sections at any given instant, while steady flow involves permanency of conditions at any particular cross section.

In hydraulics the term "pressure head," "static head" or simply "head" is used to designate the vertical height of a static column of liquid which, due to its weight, would produce a pressure equivalent to the pressure in the fluid at the point in question.

The "velocity head" is the height through which a body must fall in a vacuum to acquire the velocity with which water flows in a stream. The velocity head corresponding to any velocity is equal to the static head, which (neglecting friction) could cause (or could be caused by) that velocity. The relation between velocity head and velocity may be expressed by the formula:

$$h_v = \frac{v^2}{2g}$$

where h_v = Velocity head in feet.
v = Mean velocity in feet per second.
g = Acceleration of gravity = 32.174 feet per second per second.

Flow of Water Through Orifices and Tubes

As commonly used in hydraulics, the term orifice is used to designate an opening with a closed perimeter, and of regular shape, through which water flows. If the perimeter is not closed, or if the opening flows only partially full, the orifice becomes a weir.

An orifice with prolonged sides, such as a short piece of pipe two or three diameters in length, set in the side of a reservoir, is called a tube. An orifice in a thick wall has the hydraulic properties of a tube.

The theoretical velocity of a stream or jet of water issuing from an orifice is given by the formula:

$$v_t = \sqrt{2gh}$$

where v_t = Theoretical velocity in feet per second.
g = Acceleration of gravity = 32.174 feet per second per second.
h = Head on the center of the orifice in feet.

The actual velocity of the jet is less than the theoretical velocity because of the frictional loss which occurs as the water approaches the orifice. The ratio of the actual mean velocity, v, to the theoretical velocity, v_t, is called the "velocity coefficient" and is designated by the symbol C_v. The actual mean velocity of the jet is therefore:

$$v = C_v\sqrt{2gh}$$

The stream or jet issuing from an orifice is not in all cases the same size as the opening of the orifice because of contraction effects in certain cases and flaring effects in other cases. The "contraction coefficient," C_c, of an orifice is the ratio of the cross-sectional area of the jet to that of the orifice.

The discharge from an orifice is given by the formula:

$$Q = C_vC_a\sqrt{2gh}$$

where Q = Discharge in cubic feet per second.
a = Area of orifice opening in square feet.

It is customary to combine the coefficients C_v and C_c into a single coefficient C_d which is called a "discharge coefficient." The discharge coefficient is therefore a product of the velocity coefficient and the contraction coefficient, or $C_d = C_v \times C_c$.

The formula for discharge from an orifice then becomes:

$$Q = C_da\sqrt{2gh}$$

Table 12 gives average values of discharge coefficients for various types of orifices and tubes.

Flow of Water in Pipe and Open Channels

As the term is used in hydraulics, a pipe may be defined as a closed conduit which flows full under pressure. By open channel is meant any kind of water course with the top surface of the flowing water exposed to the atmosphere, such as a canal, aqueduct, flume, sewer or river.

The "wetted perimeter" of any conduit is that portion of the perimeter of the cross section of the conduit in contact with the liquid.

The "hydraulic radius" of a conduit is the cross-sectional area of the stream, divided by the wetted perimeter of that section. For a circular pipe flowing either full or half full the hydraulic radius is one-fourth the pipe diameter (or one-half the pipe radius).

If a tube is tapped into the wall of a vessel or pipe containing water under pressure, the water will rise in the tube to a height equal to the head producing the pressure at the point where the tube is inserted. Such a tube is called a "piezometer" tube. Piezometer tubes measure pressure above atmospheric pressure (gage pressure) since the water surface in the tube is subjected to atmospheric pressure. When piezometer tubes are used to measure pressure heads in pipes where water is in mo-

Table 12
Discharge Coefficients for Various Types of Orifices and Tubes

Diagram	Description	Average discharge coefficient, C_d
	SHARP-EDGED ORIFICE The stream is contracted to about 0.62 of the area of the opening.	0.61
	ORIFICE WITH WELL-ROUNDED ENTRY There is little or no contraction and the stream is about the same size as the opening.	0.98
	SHORT TUBE OR ORIFICE IN THICK WALL WITH SQUARE-EDGED ENTRY When flowing full. When the length of the tube is 2½ diameters it is called a "standard short tube".	0.82
	SHORT TUBE OR ORIFICE IN THICK WALL WITH SQUARE-EDGED ENTRY When the stream springs clear from the tube at the upstream corner the flow is the same as for a sharp-edged orifice.	0.61
	RE-ENTRANT TUBE Length about 2½ diameters. Flowing full.	0.73
	RE-ENTRANT TUBE When the length is about one diameter it is called "Borda's Mouthpiece". Stream springs clear of the walls of the tube.	0.52

*The material under this heading has been drawn from Technical Bulletin No. 21, recently issued by National Tube Co. of Pittsburgh, Pa.—Ed.

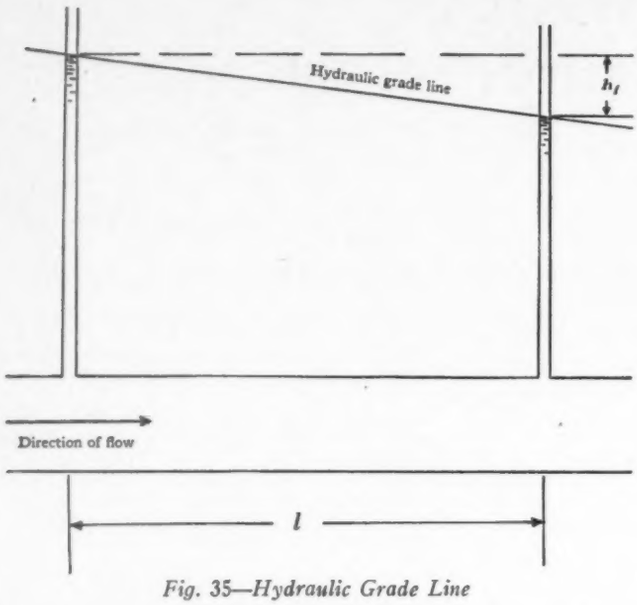

Fig. 35—Hydraulic Grade Line

tion, the end of the tube should enter the pipe at right angles to the direction of flow and the end of the tube should be flush with the inner surface of the pipe.

If a pipe full of water is provided with several piezometer tubes, a line joining the tops of the columns of water in the tubes is called the "hydraulic grade line," and the slope of this line is the "hydraulic slope" or simply the "slope." Two piezometer tubes attached to a pipe line are shown in Fig. 35. The line joining the tops of the columns of water in the tubes represents the hydraulic grade line and h_f represents the loss of head in length l. The hydraulic slope, s, is therefore:

$$s = \frac{h_f}{l}.$$

Friction

There is always friction between moving water and the surface with which the water comes into contact. There is also friction between the moving particles of the water themselves which is commonly called viscosity.

Water particles in contact with the conduit surface are retarded by friction, and viscosity causes a retardation of the particles removed from the conduit surface. Therefore, water flowing in a pipe has its maximum velocity at the center and its minimum velocity near the pipe walls.

If there were no friction losses, the theoretical velocity, v_t, at which water would discharge from a pipe or channel would be $v_t = \sqrt{2gh}$. In any long pipe or channel, however, the greater portion of the total head is used in overcoming friction.

The amount of frictional resistance offered by any surface increases with the degree of roughness of the surface. The resistance due to viscosity decreases as the temperature of the water increases.

The loss of head due to the combined effects of viscosity and friction between the moving water and the surface of the conduit is usually referred to as the loss of head due to friction.

The influences of friction and viscosity on the flow of water have been determined experimentally by various authorities and a variety of formulas for the loss of head due to friction have been derived. Only a few of the best-known and most generally used formulas will be presented in this article.

In addition to the loss of head due to friction, other losses of head result from changing the velocity or direction of flow. These special losses are considered in Table 21.

Formulas for Flow of Water In Pipe and Open Channels

The Chezy Formula

The most generally used formula for determining the velocity of flow of water in pipe and open channels is the Chezy Formula:

$$v = c\sqrt{rs}, \text{ or } v = cr^{0.5}s^{0.5}$$

where v = Mean velocity in feet per second.
r = Hydraulic radius in feet.
s = Hydraulic slope in feet per foot of length.
c = A coefficient which Chezy considered to be constant, but which is now known to vary with the hydraulic slope and hydraulic radius as well as with the degree of roughness of the surface with which the water comes in contact.

This formula, although originally designed for open channels, is with proper modification applicable to either open channels or pipe.

The Hazen-Williams Formula

For the same degree of roughness, the value of c for the Chezy Formula increases with the hydraulic slope and with the hydraulic radius. This is due to the fact that the exponents used for the terms in the formula are less than the true values. If the exponents were increased to correspond more nearly with the facts, the variation in the value of c would become smaller.

The Hazen-Williams Formula was designed with a view of obtaining a minimum variation in the value of c for all conduits of the same degree of roughness. That is, the object was to select values for the exponents such that c would be, as nearly as practicable, a function of the degree of roughness of the conduit surface and not of the hydraulic radius and slope.

The Hazen-Williams Formula is:

$$v = cr^{0.63}s^{0.54}0.001^{-0.04}$$

where v = Mean velocity in feet per second.
r = Hydraulic radius in feet.
s = Hydraulic slope in feet per foot of length.
c = Hazen-Williams coefficient of roughness.

The last term ($0.001^{-0.04}$) is a constant, and was introduced simply to equalize the value of c with the value in the Chezy Formula and other exponential formulas which may be used as a slope of 0.001 instead of at a slope of 1. Since $0.001^{-0.04}$ equals 1.318, the Hazen-Williams Formula may be written:

$$v = 1.318cr^{0.63}s^{0.54}$$

Values of Coefficient "C"

The following values of the coefficient c may be used in the Hazen-Williams Formula for computing the loss of head due to friction in new well-laid pipe:

Kind of Pipe	Coefficient c	Kind of Pipe	Coefficient c
National Duroline	148*†	Wood Stave	120
Wrought Steel	140	Riveted Steel	110
Small Brass and Copper	130	Vitrified Pipe	110
Cast Iron	130	Brick Sewers	100
Concrete	120		

*"Duroline" pipe is protected against internal corrosion and mounting friction losses by a cement base composition lining of a highly durable nature.—Ed.

†Approximately the same for cement lined pipe.—Ed.

It must be understood that these values depend upon the smoothness and regularity of the surfaces and are likely to vary in individual cases. In designing a pipe line it is customary to use somewhat lower coefficients than those above, to allow for variations due to local conditions, and for reduction of carrying capacity with age due to roughening of the inside surface, accumultaion of corrosion products, and tuberculation. However, in case of Duroline Pipe, the volume of flow remains practically unchanged over long periods of service due to the fact that rust tubercles do not form and the initially smooth inside surface is retained.

Tables 15 and 16 have been prepared to furnish directly the loss of head (h_f) in feet per 1000 feet of pipe of various sizes for different velocities and values of the coefficient c. Similar data for Duroline Pipe, based on a value of $c = 148$, is given in Table 17. These tables were calculated for actual internal diameters by the following arrangement of the Hazen-Williams Formula:

$$h_f = 1000\sqrt[0.54]{\frac{v}{1.318\,cr^{0.63}}}$$

where h_f = Loss of head in feet due to friction per 1000 feet of pipe = $1000s$.

The loss of head (h_f) for any value of the coefficient c not given in Tables 15 and 16 may be determined by multiplying the loss of head (h_f) for $c = 100$ by the factor $\sqrt[0.54]{\frac{100}{c}}$

Values of this factor corresponding to various values of the coefficient c are given below:

Coefficient c	Factor $= \sqrt[0.54]{\frac{100}{c}}$	Coefficient c	Factor $= \sqrt[0.54]{\frac{100}{c}}$
60	2.575	110	0.8382
70	1.936	120	.7135
80	1.512	130	.6152
90	1.215	140	.5363
100	1.000		

Table 15

Loss of Head in Pipe by Friction for National A.P.I. Line Pipe, Calculated by Hazen-Williams Formula

Pipe size inches	Inside diameter inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=120$	$c=100$	$c=80$
1	1.049	.3	432	0.114	0.072	0.094	0.125	0.189
		4	576	0.148	0.114	0.152	0.203	0.308
		5	720	0.185	0.173	0.230	0.308	0.468
		6	864	0.222	0.243	0.323	0.432	0.656
		8	1,152	0.296	0.414	0.551	0.737	1.12
		10	1,440	0.370	0.625	0.832	1.11	1.69
		12	1,728	0.444	0.875	1.16	1.56	2.37
		16	2,304	0.592	1.49	1.98	2.65	4.03
		20	2,880	0.740	2.27	3.01	4.03	6.13
		25	3,600	0.925	3.43	4.55	6.09	9.26
		30	4,320	1.110	4.81	6.38	8.54	13.0
		35	5,040	1.295	6.40	8.49	11.4	17.3
		40	5,760	1.480	8.14	10.8	14.5	22.1
1¼	1.380	4	576	0.085	0.030	0.040	0.053	0.080
		5	720	0.107	0.045	0.060	0.080	0.121
		6	864	0.128	0.063	0.084	0.112	0.170
		8	1,152	0.171	0.107	0.143	0.191	0.289
		10	1,440	0.214	0.162	0.215	0.287	0.436
		12	1,728	0.256	0.226	0.301	0.402	0.610
		16	2,304	0.342	0.385	0.512	0.684	1.04
		20	2,880	0.427	0.586	0.779	1.04	1.58
		25	3,600	0.534	0.886	1.18	1.57	2.39
		30	4,320	0.641	1.24	1.65	2.20	3.35
		40	5,760	0.854	2.11	2.81	3.75	5.71
		60	8,640	1.281	4.46	5.93	7.91	12.0
		80	11,520	1.708	7.59	10.1	13.5	20.5
1½	1.610	4	576	0.063	0.016	0.021	0.028	0.042
		5	720	0.079	0.024	0.032	0.042	0.064
		6	864	0.095	0.033	0.044	0.059	0.089
		8	1,152	0.126	0.056	0.075	0.100	0.152
		10	1,440	0.158	0.085	0.113	0.151	0.229
		12	1,728	0.189	0.119	0.158	0.211	0.321
		16	2,304	0.252	0.202	0.269	0.360	0.545
		20	2,880	0.315	0.308	0.410	0.548	0.830
		25	3,600	0.394	0.466	0.620	0.828	1.25
		30	4,320	0.473	0.652	0.868	1.16	1.76
		40	5,760	0.630	1.11	1.48	1.97	2.99
		60	8,640	0.945	2.34	3.12	4.16	6.31
		80	11,520	1.260	3.99	5.31	7.09	10.8
		100	14,400	1.576	6.03	8.02	10.7	16.2
		120	17,280	1.891	8.45	11.2	15.0	22.7
2	2.067	6	8,640	0.574	0.802	1.19	1.66	2.51
		8	11,520	765	1.52	2.02	2.83	4.28
		10	14,400	956	2.30	3.06	4.28	6.47
		12	17,280	1 147	3.22	4.28	6.00	9.07
		16	23,040	1 530	5.48	7.30	10.2	15.5
		20	28,800	1 912	8.29	11.3	15.5	23.3
		30	43,200	2.868	17.6	23.4	32.8	49.5
		50	72,000	4.781	45.2	60.2	84.3	128.
		75	108,000	7.171	95.8	128.	179.	270.
		100	144,000	9.561	163.	217.	304.	460.
		150	216,000	14.342	346.	460.	645.	975.
		200	288,000	19.122	589.	784.	1099.	1661.

Pipe size inches	Inside diameter inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=130$	$c=120$	$c=100$
2½	2.469	8	11,520	0.536	0.639	0.733	0.851	1.19
		10	14,400	.670	.966	1.11	1.29	1.80
		12	17,280	.804	1.35	1.55	1.80	2.53
		16	23,040	1.072	2.31	2.65	3.07	4.30
		20	28,800	1.340	3.49	4.00	4.64	6.51
		25	36,000	1 675	5.27	6.05	7.02	9.83
		50	72,000	3.351	19.0	21.8	25.3	35.5
		100	144,000	6.701	68.7	78.8	91.4	128.
		150	216,000	10.052	146.	167.	194.	271.
		200	288,000	13.402	248.	284.	330.	462.
		250	360,000	16.753	375.	430.	499.	699.
		300	432,000	20.103	526.	603.	699.	980.
3	3.068	10	14,400	0.434	0.336	0.385	0.446	0.626
		15	21,600	.651	.711	.816	.946	1.33
		20	28,800	.868	1.21	1.39	1.61	2.26
		25	36,000	1.085	1.83	2.10	2.44	3.41
		50	72,000	2.170	6.61	7.58	8.79	12.3
		100	144,000	4.340	23.9	27.4	31.7	44.5
		200	288,000	8.680	86.1	98.8	115.	161.
		300	432,000	13.020	182.	209.	243.	340.
		400	576,000	17.360	311.	357.	414.	580.
		500	720,000	21.699	470.	539.	625.	876.
3½	3.548	10	14,400	0 325	0.165	0.190	0.220	0.308
		15	21,600	.487	.350	.402	.466	.653
		20	28,800	.649	.597	.684	.794	1.11
		25	36,000	.811	.902	1.03	1.20	1.68
		50	72,000	1.623	3.26	3.73	4.33	6.07
		100	144,000	3.245	11.8	13.5	15.6	21.9
		200	288,000	6.490	42.4	48.7	56.4	79.1
		300	432,000	9.735	89.9	103.	120.	168.
		400	576,000	12.980	153.	176.	204.	286.
		500	720,000	16.225	231.	266.	308.	432.
		600	864,000	19.470	324.	372.	432.	605.
4	4.026	20	28,800	0.504	0.322	0.370	0.429	0.601
		25	36,000	.630	.487	.559	.648	.909
		30	43,200	.756	.683	.784	.909	1.27
		40	57,600	1.008	1.16	1.33	1.55	2.17
		50	72,000	1.260	1.76	2.02	2.34	3.28
		100	144,000	2.520	6.33	7.28	8.45	11.8
		200	288,000	5.040	22.9	26.3	30.5	42.7
		300	432,000	7.561	48.6	55.7	64.6	90.6
		400	576,000	10.081	82.7	94.9	110.	154.
		500	720,000	12.601	125.	143.	166.	233.
		600	864,000	15.121	175.	201.	233.	327.
		800	1,152,000	20.162	299.	343.	397.	557.

Pipe size inches	Inside diameter inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=130$	$c=120$	$c=100$
5	5.047	30	43,200	0.481	0.227	0.261	0.302	0.424
		40	57,600	.642	.387	.441	.515	.722
		50	72,000	.802	.585	.671	.779	1.09
		100	144,000	1.604	2.11	2.42	2.81	3.94
		200	288,000	3.208	7.63	8.75	10.1	14.2
		300	432,000	4.812	16.2	18.5	21.5	30.1
		400	576,000	6.416	27.5	31.6	36.6	51.3
		500	720,000	8.020	41.6	47 7	55.3	77.6
		750	1,080,000	12.030	88.2	101.	117.	164.
		1000	1,440,000	16.040	150.	172.	200.	280.

Pipe size inches	Inside diameter inches	Discharge in Gallons per 24 hours	Discharge in Cubic feet per second	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=130$	$c=120$	$c=100$
6	6.065	50,000	0.0774	0.386	0.122	0.140	0.162	0.227
		60,000	0.928	.463	.171	.196	.227	.318
		80,000	.124	.617	.291	.333	.387	.542
		100,000	.155	.771	.439	.504	.585	.819
		200,000	.309	1.542	1.59	1.82	2.11	2.96
		300,000	.464	2.314	3.36	3 85	4.47	6.27
		400,000	.619	3.085	5.72	6.57	7.62	10.7
		600,000	.928	4.627	12.1	13.9	16.1	22.6
		800,000	1.238	6.170	20.7	23.7	27.5	38.5
		1,000,000	1.547	7.712	31.2	35.8	41.6	58.2
		1,500,000	2.321	11.568	66.2	75.9	88.1	123.
		2,000,000	3.094	15.424	113.	129.	150.	210.
8	7.981	200,000	0.309	0.891	0.416	0.478	0.554	0.777
		300,000	.464	1.336	.882	1.01	1.17	1.65
		400,000	.619	1.781	1.50	1.72	2.00	2.80
		500,000	.774	2.227	2.27	2.61	3.02	4.24
		750,000	1.160	3.340	4.82	5.52	6.41	8.98
		1,000,000	1.547	4.454	8.20	9.41	10.9	15.3
		1,500,000	2.321	6.680	17.4	19.9	23.1	32.4
		2,000,000	3.094	8.907	29.6	34.0	39.4	55.2
		3,000,000	4.642	13.361	62.7	72.0	83.5	117.
10	10.020	300,000	0.464	0.848	0.291	0.334	0.388	0.543
		400,000	.619	1.130	.496	.569	.660	.926
		500,000	.774	1.413	.750	.861	.998	1.40
		750,000	1.160	2.119	1.59	1.82	2.12	2.96
		1,000,000	1.547	2.825	2.71	3.11	3.60	5.05
		2,000,000	3.094	5.651	9.78	11.2	13.0	18.2

Pipe size inches	Inside diameter inches	Discharge in Gallons per 24 hours	Discharge in Cubic feet per second	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=130$	$c=120$	$c=100$
10	10.020	3,000,000	4.642	8.476	20.7	23.8	27.6	38.6
		4,000,000	6.189	11.302	35.3	40.5	47.0	65.8
		5,000,000	7.736	14.127	53.4	61.2	71.0	99.5
12	12.000	300,000	0.464	0.591	0.121	0.139	0.161	0.226
		400,000	.619	.788	.206	.237	.274	.385
		500,000	.774	.985	.312	.358	.415	.581
		1,000,000	1.547	1.970	1.13	1.29	1.50	2.10
		1,500,000	2.321	2.955	2.38	2.74	3.17	4.45
		2,000,000	3.094	3.940	4.06	4.66	5.40	7.58
		3,000,000	4.642	5.910	8.61	9.87	11.5	16.1
		5,000,000	7.736	9.859	22.2	25.4	29.5	41.3
		7,500,000	11.60	14.775	47.0	53.9	62.5	87.6
		10,000,000	15.47	19.700	80.0	91.8	106.	149.
14 O D	13.250	500,000	0.774	0.808	0.192	0.221	0.256	0.359
		1,000,000	1.547	1.616	.695	.797	.924	1.30
		2,000,000	3.094	3.232	2.51	2.88	3.34	4.68
		3,000,000	4.642	4.847	5.31	6.09	7.07	9.91
		5,000,000	7.736	8.079	13.7	15.7	18.2	25.5
		7,500,000	11.60	12.119	29.0	33.3	38.6	54.1
		10,000,000	15.47	16.158	49.4	56.6	65.7	92.1
		12,500,000	19.34	20.198	74.7	85.6	99.3	139.
16 O D	15.250	750,000	1.160	0.915	0.206	0.236	0.274	0.383
		1,000,000	1.547	1.220	.350	.402	.466	.653
		2,000,000	3.094	2.440	1.26	1.45	1.68	2.36
		3,000,000	4.642	3.659	2.68	3.07	3.56	5.00
		5,000,000	7.736	6.099	6.90	7.91	9.18	12.9
		7,500,000	11.60	9.148	14.6	16.8	19.4	27.3
		10,000,000	15.47	12.198	24.9	28.6	33.1	46.4
		15,000,000	23.21	18.297	52.8	60.5	70.2	98.4
18 O D	17.182	1,000,000	1.547	.961	0.196	0.225	0.261	0.365
		2,000,000	3.094	1.922	.707	.811	.941	1.32
		3,000,000	4.642	2.883	1.50	1.72	1.99	2.79
		5,000,000	7.736	4.805	3.86	4.43	5.13	7.20
		7,500,000	11.60	7.207	8.18	9.38	10.9	15.2
		10,000,000	15.47	9.609	13.9	16.0	18.5	26.0
		15,000,000	23.21	14.414	29.5	33.9	39.3	55.0
		20,000,000	30.94	19.218	50.3	57.7	66.9	93.8
20 O D	19.182	1,000,000	1.547	0.771	0.115	0.131	0.152	0.214
		2,000,000	3.094	1.542	.414	.475	.550	.771
		3,000,000	4.642	2.313	.876	1.01	1.17	1.63
		5,000,000	7.736	3.855	2.26	2.59	3.00	4.21
		7,500,000	11.60	5.782	4.78	5.49	6.36	8.92
		10,000,000	15.47	7.710	8.15	9.35	10.8	15.2
		15,000,000	23.21	11.565	17.3	19.8	23.0	32.2
		20,000,000	30.94	15.419	29.4	33.7	39.1	54.8

Table 16

Loss of Head in Pipe by Friction for Large Diameter Pipe Listed by I. D. Sizes, Calculated by Hazen-Williams Formula

Pipe inside diameter		Discharge in		Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f)			
Inches	Feet (D)	Million gallons per 24 hours	Cubic feet per second		c=140	c=130	c=120	c=100
22	1.8333	1	1.547	0.586	0.059	0.067	0.078	0.110
		2.5	3.868	1.465	.321	.368	.427	.598
		5	7.736	2.931	1.16	1.33	1.54	2.16
		7.5	11.60	4.396	2.45	2.81	3.26	4.57
		10	15.47	5.861	4.18	4.79	5.56	7.79
		15	23.21	8.792	8.86	10.2	11.8	16.5
		20	30.94	11.722	15.1	17.3	20.1	28.1
		25	38.68	14.653	22.8	26.2	30.3	42.5
24	2.0000	2	3.094	0.985	0.139	0.159	0.185	0.259
		5	7.736	2.462	.758	.869	1.01	1.41
		7.5	11.60	3.694	1.61	1.84	2.14	2.99
		10	15.47	4.925	2.74	3.14	3.64	5.10
		15	23.21	7.387	5.80	6.65	7.71	10.8
		20	30.94	9.850	9.87	11.3	13.1	18.4
		25	38.68	12.312	14.9	17.1	19.9	27.8
		30	46.42	14.775	20.9	24.0	27.8	39.0
26	2.1667	2	3.094	0.839	0.094	0.108	0.125	0.175
		5	7.736	2.098	.513	.589	.683	.957
		7.5	11.60	3.147	1.09	1.25	1.45	2.03
		10	15.47	4.196	1.85	2.12	2.46	3.45
		15	23.21	6.295	3.93	4.50	5.22	7.32
		20	30.94	8.393	6.69	7.67	8.90	12.5
		25	38.68	10.491	10.1	11.6	13.4	18.8
		30	46.42	12.589	14.2	16.3	18.8	26.4
28	2.3333	2	3.094	0.724	0.066	0.075	0.087	0.122
		5	7.736	1.809	.358	.410	.476	.667
		7.5	11.60	2.714	.758	.869	1.01	1.41
		10	15.47	3.618	1.29	1.48	1.72	2.41
		15	23.21	5.428	2.74	3.14	3.64	5.10
		20	30.94	7.237	4.66	5.35	6.20	8.69
		25	38.68	9.046	7.05	8.08	9.37	13.1
		30	46.42	10.855	9.88	11.3	13.1	18.4
30	2.5000	5	7.736	1.576	0.256	0.293	0.340	0.477
		10	15.47	3.152	.923	1.06	1.23	1.72
		15	23.21	4.728	1.96	2.24	2.60	3.65
		20	30.94	6.304	3.33	3.82	4.43	6.21
		25	38.68	7.880	5.03	5.78	6.70	9.39
		30	46.42	9.456	7.06	8.10	9.39	13.2
		35	54.15	11.032	9.39	10.8	12.5	17.5
		40	61.89	12.608	12.0	13.8	16.0	22.4
36	3.0000	5	7.736	1.094	0.105	0.121	0.140	0.196
		10	15.47	2.189	.380	.436	.505	.708
		15	23.21	3.283	.804	.923	1.07	1.50
		20	30.94	4.378	1.37	1.57	1.82	2.56
		30	46.42	6.567	2.90	3.33	3.86	5.41
		40	61.89	8.756	4.95	5.67	6.58	9.22
		50	77.36	10.944	7.48	8.58	9.95	13.9
		60	92.83	13.133	10.5	12.0	13.9	19.5

Pipe inside diameter		Discharge in		Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f)			
Inches	Feet (D)	Million gallons per 24 hours	Cubic feet per second		c=140	c=130	c=120	c=100
42	3.50	5	7.736	0.804	0.050	0.057	0.066	0.093
		10	15.47	1.608	.179	.206	.238	.334
		15	23.21	2.412	.380	.436	.505	.708
		20	30.94	3.216	.647	.742	.861	1.21
		30	46.42	4.824	1.37	1.57	1.82	2.56
		40	61.89	6.433	2.34	2.68	3.11	4.35
		50	77.36	8.041	3.53	4.05	4.70	6.58
		75	116.0	12.061	7.48	8.58	9.95	13.9
48	4.00	5	7.736	0.616	0.026	0.030	0.034	0.048
		10	15.47	1.231	.094	.107	.124	.174
		20	30.94	2.462	.338	.387	.449	.630
		30	46.42	3.694	.715	.821	.952	1.33
		40	61.89	4.925	1.22	1.40	1.62	2.27
		50	77.36	6.156	1.84	2.11	2.45	3.44
		75	116.0	9.234	3.90	4.48	5.19	7.28
		100	154.7	12.312	6.65	7.63	8.85	12.4
54	4.50	10	15.47	0.973	0.053	0.060	0.070	0.098
		20	30.94	1.946	.190	.218	.253	.355
		30	46.42	2.919	.403	.462	.536	.752
		40	61.89	3.891	.687	.788	.913	1.28
		50	77.36	4.864	1.04	1.19	1.38	1.94
		75	116.0	7.296	2.20	2.52	2.93	4.10
		100	154.7	9.728	3.75	4.30	4.98	6.99
		125	193.4	12.160	5.66	6.50	7.54	10.6
60	5.00	10	15.47	0.788	0.032	0.036	0.042	0.059
		20	30.94	1.576	.114	.131	.151	.212
		30	46.42	2.364	.241	.277	.321	.450
		40	61.89	3.152	.411	.471	.547	.766
		50	77.36	3.940	.621	.713	.827	1.16
		75	116.0	5.910	1.32	1.51	1.75	2.45
		100	154.7	7.880	2.24	2.57	2.98	4.18
		125	193.4	9.850	3.39	3.89	4.51	6.32
66	5.50	10	15.47	0.651	0.020	0.023	0.026	0.037
		20	30.94	1.302	.072	.082	.095	.133
		30	46.42	1.954	.152	.174	.202	.283
		50	77.36	3.256	.391	.448	.520	.728
		75	116.0	4.884	.828	.949	1.10	1.54
		100	154.7	6.512	1.41	1.62	1.88	2.63
		125	193.4	8.140	2.13	2.44	2.84	3.97
		150	232.1	9.769	2.99	3.43	3.97	5.57
72	6.00	10	15.47	0.547	0.013	0.015	0.017	0.024
		25	38.68	1.368	.071	.081	.094	.132
		50	77.36	2.736	.256	.293	.340	.477
		75	116.0	4.104	.542	.621	.721	1.01
		100	154.7	5.472	.923	1.06	1.23	1.72
		125	193.4	6.840	1.40	1.60	1.86	2.60
		150	232.1	8.208	1.96	2.24	2.60	3.65
		175	270.8	9.576	2.60	2.98	3.46	4.85

Pipe inside diameter		Discharge in		Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f)			
Inches	Feet (D)	Cubic feet per second	Million gallons per 24 hours		c=140	c=130	c=120	c=100
78	6.50	25	16.16	0.753	0.021	0.025	0.028	0.040
		50	32.32	1.507	.077	.089	.103	.144
		75	48.47	2.260	.163	.188	.217	.305
		100	64.63	3.014	.278	.319	.371	.519
		150	96.95	4.520	.590	.677	.785	1.10
		200	129.3	6.027	1.01	1.15	1.34	1.87
		250	161.6	7.534	1.52	1.74	2.02	2.83
		300	193.9	9.041	2.13	2.44	2.83	3.97
84	7.00	25	16.16	0.650	0.015	0.017	0.020	0.028
		50	32.32	1.299	.054	.062	.072	.100
		75	48.47	1.949	.114	.131	.152	.212
		100	64.63	2.598	.194	.223	.258	.362
		150	96.95	3.898	.411	.472	.547	.767
		200	129.3	5.197	.701	.804	.932	1.31
		250	161.6	6.496	1.06	1.22	1.41	1.98
		300	193.9	7.795	1.48	1.70	1.98	2.77
90	7.50	25	16.16	0.566	0.011	0.012	0.014	0.020
		50	32.32	1.132	.038	.044	.051	.072
		75	48.47	1.698	.081	.093	.108	.152
		100	64.63	2.264	.139	.159	.185	.259
		150	96.95	3.395	.294	.337	.391	.548
		200	129.3	4.527	.501	.574	.666	.934
		300	193.9	6.791	1.06	1.22	1.41	1.98
		400	258.5	9.054	1.81	2.07	2.40	3.37
96	8.00	25	16.16	0.497	0.008	0.009	0.010	0.014
		50	32.32	0.995	.028	.032	.037	.052
		100	64.63	1.989	.101	.116	.135	.189
		150	96.95	2.984	.215	.246	.286	.400
		200	129.3	3.979	.366	.419	.486	.682
		300	193.9	5.968	.775	.889	1.03	1.44
		400	258.5	7.958	1.32	1.51	1.76	2.46
		500	323.2	9.947	2.00	2.29	2.65	3.72

The Scobey Formula

Fred C. Scobey,* Senior Irrigation Engineer of the Division of Agricultural Engineering, U. S. Department of Agriculture, offers the following formulas which he says "include viscosity influence for a temperature of 15° C. (59° F.) and differentiate between various types and classes of sheet and plate metal pipe by means of coefficients, which are themselves constant throughout the whole range of sizes and velocities for a given class of pipe":

$$hf = \frac{K_s v^{1.9}}{D^{1.1}}$$

$$v = \frac{hf^{.0526} D^{0.58}}{K_s^{.0526}}$$

where hf = Loss of head in feet due to friction per 1000 feet of pipe.
D = Mean inside diameter of pipe in feet.
v = Mean velocity of the water in feet per second.
K_s = General coefficient. (K'_s is this value for new pipe.)

Scobey limited his study to pipe of nominal size, four inch and larger, and assumed that the interior of all pipe would be chemically protected with a coating which would form the true interior surface, at least during the first years of the life of the conduit.

He divides sheet and plate metal pipe into three major classes:

Class 1—"Full-riveted" pipe, having both longitudinal and girth seams held by one or more lines of rivets with projecting

*United States Department of Agriculture Technical Bulletin No. 150 "The Flow of Water in Riveted Steel and Analogous Pipes" (1930).

Table 17

Loss of Head in Pipe by Friction for National Duroline Pipe*
Calculated by the Hazen-Williams Formula

Pipe size, inches	Average inside diameter, inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) ($c = 148$)
½	0.484	1	1,440	1.74	35.0
		2	2,880	3.48	126.0
		3	4,320	5.23	265.0
		4	5,760	6.97	455.0
		5	7,200	8.72	685.0
		6	8,640	10.46	970.0
		8	11,520	13.95	1650.0
		10	14,400	17.44	2500.0
¾	0.686	2	2,880	1.73	22.8
		3	4,320	2.60	48.0
		4	5,760	3.47	82.0
		5	7,200	4.34	124.0
		6	8,640	5.21	173.0
		8	11,520	6.94	295.0
		10	14,400	8.68	443.0
		15	21,600	13.02	946.0
		20	28,800	17.36	1590.0
1	0.896	3	4,320	1.52	13.2
		4	5,760	2.03	22.2
		5	7,200	2.54	34.5
		6	8,640	3.05	47.5
		8	11,520	4.07	81.0
		10	14,400	5.08	120.0
		12	17,280	6.10	170.0
		14	20,160	7.12	225.0
		16	23,040	8.14	290.0
		20	28,800	10.16	432.0
		25	36,000	12.70	630.0
		30	43,200	15.24	925.0
1¼	1.175	4	5,760	1.18	5.8
		5	7,200	1.47	9.0
		6	8,640	1.77	12.6
		7	10,080	2.07	16.7
		8	11,520	2.36	21.5
		10	14,400	2.95	32.5
		12	17,280	3.55	45.5
		14	20,160	4.14	59.0
		16	23,040	4.73	77.0
		18	25,920	5.32	96.0
1¼	1.175	20	28,800	5.91	116.0
		25	36,000	7.39	175.0
		30	43,200	8.87	245.0
		40	57,600	11.80	420.0
		60	86,400	17.70	880.0
1½	1.405	4	5,760	0.82	2.60
		5	7,200	1.03	3.95
		6	8,640	1.24	5.28
		7	10,080	1.44	7.3
		8	11,520	1.65	9.4
		9	12,960	1.86	11.6
		10	14,400	2.06	14.2
		12	17,280	2.48	19.8
		14	20,160	2.89	26.4
		16	23,040	3.31	34.5
		18	25,920	3.72	42.0
		20	28,800	4.13	51.0
		22	31,680	4.55	61.0
		24	34,560	4.96	72.0
		26	37,440	5.38	83.0
		28	40,320	5.79	95.0
		30	43,200	6.20	108.0
		35	50,400	7.24	135.0
		40	57,600	8.27	176.0
		50	72,000	10.34	266.0
		75	108,000	15.51	562.0
		100	144,000	20.69	960.0
2	1.780	6	8,640	0.77	1.66
		8	11,520	1.03	2.82
		10	14,400	1.28	4.30
		12	17,280	1.54	6.0
		14	20,160	1.80	8.0
		16	23,040	2.06	10.2
2	1.780	18	25,920	2.32	12.7
		20	28,800	2.57	15.5
		25	36,000	3.22	23.2
		30	43,200	3.86	33.0
		35	50,400	4.51	44.0
		40	57,600	5.15	56.0
		45	64,800	5.80	77.0
		50	72,000	6.44	84.0
		55	79,200	7.09	100.0
		60	86,400	7.73	117.0
		65	93,600	8.37	135.0
		70	100,800	9.02	157.0
		75	108,000	9.66	177.0
		100	144,000	12.89	302.0
		150	216,000	19.33	570.0
2½	2.182	8	11,250	0.68	1.05
		10	14,400	.85	1.58
		12	17,280	1.02	2.25
		16	23,040	1.37	3.85
		25	36,000	2.14	8.6
		50	72,000	4.29	31.5
		100	144,000	8.58	113.0
		150	216,000	12.87	240.0
		200	288,000	17.16	410.0
		250	360,000	21.45	620.0
3	2.725	10	14,400	0.55	0.54
		15	21,600	.82	1.15
		20	28,800	1.10	1.95
		25	36,000	1.37	2.95
		50	72,000	2.75	10.6
		80	115,200	4.40	25.3
		100	144,000	5.50	38.5
		160	230,400	8.80	90.0
		200	288,000	11.00	136.0
		300	432,000	16.50	290.0
		400	576,000	22.00	500.0
		500	720,000	27.50	750.0
3½	3.205	10	14,400	0.39	0.24
		15	21,600	.59	.52
		20	28,800	.79	.88
		25	36,000	.99	1.34
		50	72,000	1.98	4.8
		80	115,200	3.18	11.5
		100	144,000	3.97	17.5
		160	230,400	6.36	41.5
		200	288,000	7.95	63.0
		300	432,000	11.93	135.0
		400	576,000	15.90	225.0
		500	720,000	19.88	340.0
4	3.620	20	28,800	0.62	0.49
		25	36,000	.77	.74
		30	43,200	.93	1.04
		50	72,000	1.55	2.68
		80	115,200	2.49	6.4
		100	144,000	3.11	9.7
		160	230,400	4.98	23.4
		200	288,000	6.23	35.0
		300	432,000	9.35	72.2
		400	576,000	12.46	124.0
		500	720,000	15.58	187.0
5	4.548	30	43,200	0.59	0.34
		40	57,600	.79	.58
		50	72,000	.98	.87
		80	115,200	1.58	2.10
		100	144,000	1.97	3.15
		160	230,400	3.16	7.7
		200	288,000	3.95	11.5
		300	432,000	5.92	24.2
		400	576,000	7.90	41.2
		500	720,000	9.87	61.8
		750	1,080,000	14.81	131.0
6	5.440	50,000	.0774	0.47	0.20
		60,000	.0928	.57	.26
		80,000	.1238	.76	.44
		100,000	.1547	.95	.66
		140,000	.2166	1.34	1.25
		200,000	.3094	1.91	3.42
		300,000	.4642	2.87	5.2
		400,000	.619	3.83	8.7
		500,000	.774	4.79	13.2
		600,000	.928	5.75	18.5
		800,000	1.238	7.67	31.5
		1,000,000	1.547	9.58	48.0
		1,500,000	2,321	14.37	100.0
		2,000,000	3.094	19.17	170.0
8	7.446	200,000	.3094	1.02	0.53
		300,000	.4642	1.53	1.12
		360,000	.557	1.84	1.57
		400,000	.619	2.04	1.92
		500,000	.774	2.55	2.88
		600,000	.928	3.06	4.05
		700,000	1.083	3.58	5.4
		800,000	1.238	4.09	6.9
		900,000	1.392	4.60	8.6
		1,000,000	1.547	5.11	10.5
		1,200,000	1.857	6.13	14.6
8	7.356	200,000	.3094	1.04	0.56
		300,000	.4642	1.57	1.18
		400,000	.619	2.09	2.00
		500,000	.774	2.62	3.05
		600,000	.928	3.14	4.30
		700,000	1.083	3.66	5.7
		800,000	1.238	4.19	7.3
		1,000,000	1.547	5.24	11.2
		1,500,000	2.321	7.86	23.8
		2,000,000	3.094	10.48	40.0
		3,000,000	4.642	15.72	84.0
10	9.443	300,000	.4642	0.95	0.35
		400,000	.619	1.27	.60
		500,000	.774	1.59	.90
		600,000	.928	1.90	1.26
		750,000	1.160	2.38	1.92
		1,000,000	1.547	3.18	3.25
		1,500,000	2.321	4.77	6.9
		2,000,000	3.094	6.36	11.8
		3,000,000	4.642	9.54	25.0
		4,000,000	6.188	12.72	42.5
12	11.363	500,000	.774	1.11	0.45
		600,000	.928	1.33	.63
		700,000	1.083	1.55	.84
		800,000	1.238	1.77	1.08
		900,000	1.392	1.99	1.34
		1,000,000	1.547	2.21	1.63
		1,500,000	2.321	3.32	3.45
		2,000,000	3.094	4.43	5.9
		3,000,000	4.642	6.64	12.5
		4,000,000	6.188	8.86	21.3
		5,000,000	7.736	11.07	32.2
		6,000,000	9.283	13.29	45.2
		7,000,000	10.830	15.50	60.2
		8,000,000	12.378	17.72	77.2
		9,000,000	13.925	19.93	96.2
		10,000,000	15.472	22.15	117.0
		12,000,000	18.567	26.58	164.0
		14,000,000	21.661	31.01	218.0
		16,000,000	24.756	35.44	280.0
		18,000,000	27.850	39.87	348.0
		20,000,000	30.945	44.30	424.0

*Pipe lined with a highly resistant cement-base composition lining.—Ed.

heads. From the capacity standpoint, pipe with countersunk rivet heads on the interior belong in *Class* 3.

Class 2—"Girth-riveted" pipe, having no retarding rivet heads in the longitudinal seams, but having the same girth seams as full-riveted pipe.

Class 3—"Continuous-interior" pipe, having the interior surface unmarred by plate offsets or by projecting rivet heads in either longitudinal or girth seams. Not necessarily described as "smooth."

For these classes Scobey suggests the following coefficients for new pipe:

Class 1*a*, $K'_s = 0.38$ for new sheet metal pipe up to three-sixteenths of an inch thick.

Class 1*b*, $K'_s = 0.44$ for new plate metal pipe on three-sixteenths to seven-sixteenths of an inch thick, with either taper or cylinder joints.

Class 1*c*, $K'_s = 0.48$ for new plate metal pipe from one-half inch up, with either taper or cylinder joints, and for plate from one-fourth to seven-sixteenths of an inch thick when butt-jointed.

Class 1*d*, $K'_s = 0.52$ for new butt-strap pipe of plate from one-half inch up.

Class 2*d*, $K'_s = 0.34$ for new girth-riveted pipe. This includes all sheet and plate metal pipe with continuous seamed lognitudinal joints but with girth joints, particularly field joints, made with the usual rivet heads inside the pipe.

Class 3, $K'_s = 0.32$ for new continuous-interior pipe. This class comprises all type of sheet and plate metal pipe that offer a practically uniform interior surface of relative smoothness. "Continuous-interior" is offered as descriptive of an interior surface unbroken by rivet heads or appreciable shell-thickness offsets. Use of the apparently obvious synonym "smooth" has purposely been avoided, as this description might hold only while the pipe is new.

NOTE: Although Scobey confines his paper to the discussion of sheet and plate metal pipe, *Classes* 2 and 3 also apply to seamless pipe as well as to lap-weld, hammer-weld, and electric-weld pipe.

It should be noted that the coefficients (K'_s) given above

are for new pipe. Concerning the deterioration of carrying capacity with age, Scobey states:

"It has long been appreciated that all metal pipe deteriorates in carrying capacity; the rate of decrease being dependent on the efficiency of the pipe coating, the composition and treatment of the pipe material, and the activity of the water conveyed in the pipe. Filtered and treated water causes less deterioration than raw water. Long lines deteriorate more rapidly at the upper ends than at the lower ends. "So far as available data indicate, the increase in the value of K_s with age, is expressed by the formula:

$$K_s = K'_s e^{0.015t}$$

where e = Base of Naperian logarithms (2.7183).
t = Age of pipe in years.
When t is zero, then K_s becomes K'_s."

[NOTE: Tables showing various values of K_s and corresponding losses of head at various velocities and also values of $v^{1.9}$ have had to be omitted. For a copy of these address National Tube Co., Pittsburgh, Pa., asking for Technical Bulletin No. 21. —Ed.]

Fig. 36, which was taken from United States Department of Agriculture Technical Bulletin No. 150, will be found useful in making estimates and preliminary studies. It gives the relation between discharge, pipe diameter, velocity, and loss of head for various values of the coefficient K_s. Values of K_s for ages of 0 to 50 years corresponding to various values of K'_s are also given.

The lower age diagram on the chart is based on the formula $K_s = K'_s e^{0.015t}$ and is to be used for aggressive waters. The upper age diagram is based on the formula $K_s = K'_s e^{0.01t}$ and is intended for use where the waters are known to be non-aggressive.

The following example will illustrate the method of using this chart:

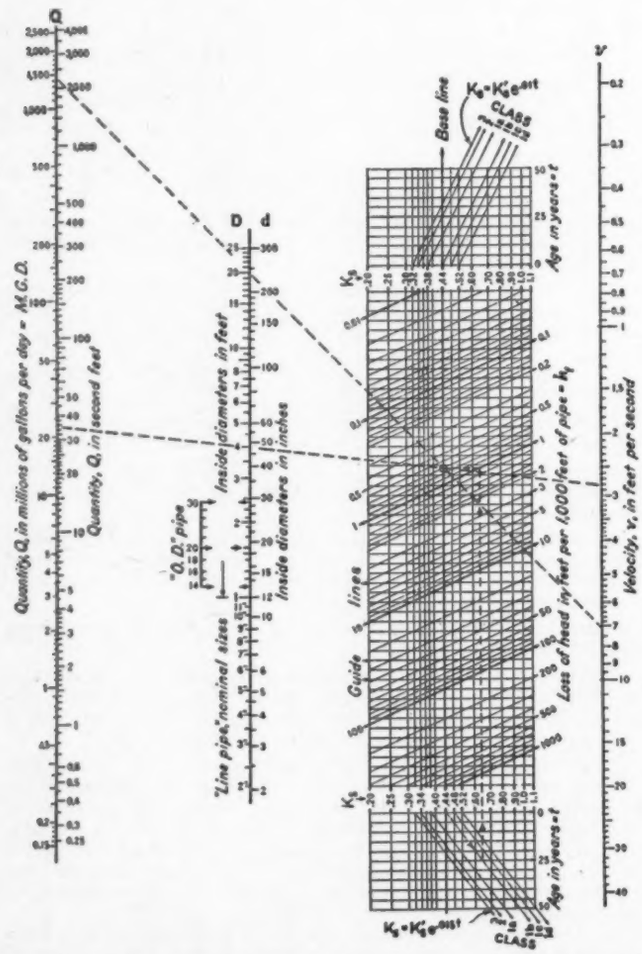
Q
D d
v
Quantity, Q, in millions of gallons per day = M.G.D.
Quantity, Q, in cubic feet per second
Inside diameters in feet
Inside diameters in inches
"O.D." pipe
"Line pipe" nominal sizes
Guide lines
Loss of head in feet per 1,000 feet of pipe = K_s
Velocity, v, in feet per second
Base line
$K_s = K'_s e^{0.01t}$
$K_s = K'_s e^{0.015t}$
CLASS
Age in years = t

Fig. 36 — Chart Showing Relation Between Discharge Pipe Diameter, Velocity, and Loss of Head for Various Values of the Coefficient K_s and K_{s1} in Scobey Formula

Table 21

Special Losses of Head in Terms of $v^2/2g$ (From Hydraulics, by Ernest W. Schoder and Francis M. Dawson—Second Edition, 1934, with Modifications)

Nature of special resistance	Loss of head as decimal or multiple of $v^2/2g$*
Entrance	
Square-edged entry. Upstream end of pipe perpendicular to, and flush with inside face of reservoir wall	0.50
Projecting pipe at entry or re-entrant pipe end	1.00
Well-rounded entry	0.02 to 0.05
Curves and Fittings	
Easy curves or bends of very large radius, and smooth inside, of same inside diameter throughout as the pipe line. Excess loss over same length of straight pipe	0.05 to 0.15
90-degree curves, fairly smooth, same inside diameter as pipe; Radius of center line = diameter of pipe	0.50
Radius of center line = 2 to 8 times diameter of pipe	0.25
90-degree common screw end pipe elbows, short turn, inside larger than pipe	0.75
Tees, common screw end, full-size branch, flow deviated 90 degrees	1.50
Square elbow (intersection of two cylinders, corner not rounded at outside or inside of curve.)	1.25
Obtuse-angled elbows, (deflection of pipe less than 90 degrees); multiply values for square elbow or 90-degree curve by $\left(\frac{\text{deflection, degrees}}{90 \text{ degrees}}\right)^2$	
Water Meters (Subject to much variation)	
Disk or "wobble-disk" type	3.4 to 10
Rotary type (star or cog-wheel-shaped disk as piston)	10
Reciprocating piston type (like a piston pump)	15
Turbine-wheel type (double flow, balanced)	5 to 7.5
Diaphragm and Orifice Meters	
Diaphragm of thin material across pipe, with concentric hole, or an inside projecting washer or gasket, or a "burr", due to cutting pipe with a wheel cutter: Diameter of hole = 0.91 × diameter of pipe	0.34
Diameter of hole = 0.80 × diameter of pipe	1.88
(Note that $v^2/2g$ in this particular case refers to pipe, not to the area of opening, nor to the contracted stream through opening.)	
Nozzles	
Nozzles: when the coefficient of velocity and discharge ranges from 0.99 to 0.975, the loss of head ranges from	0.02 to 0.05 (Where v is the velocity of the issuing jet)

*Note: Except where otherwise noted, v is the mean velocity in the pipe.

Assume that it is desired to know what conditions will prevail in a pipe line constructed of full-riveted pipe (*Class* 1*b*) after carrying aggressive waters for a period of 25 years.

From page 45 the coefficient K_s for new pipe of *Class* 1*b* is found to be 0.44. On the lower age diagram follow the diagonal line representing $K_s = 0.44$ (at 0 age) until it intersects the horizontal line representing an age of 25 years. From this point of intersection proceed vertically on the dashed line (which represents $K_s = 0.64$) until it intersects the slope line of 1 foot per 1000 feet of pipe. From this point follow the guide lines to the vertical base line. Using this point (marked on the chart by a circle) as a pivot, a straight edge will give simultaneous values of discharge (Q) diameter (D or d) and velocity (v). This is illustrated by dashed lines for 20 feet and 4 feet inside diameter pipe. The dashed line through the pivot point and the point representing pipe of 20 feet inside diameter shows that a discharge of 2250 cubic feet per second and a velocity of 7.2 feet per second can be expected. The other dashed line through the pivot point and through the point representing pipe 4 feet inside diameter indicates a discharge of 36 cubic feet per second and a velocity of 2.8 feet per second.

Special Losses of Head

Curves, elbows, tees, meters, enlargements, contractions, etc., in a pipe line cause losses of head, which, if of consequence, must be allowed for in addition to the loss of head ordinarily encountered in straight pipe of uniform cross section.

Special losses may be expressed as equivalent lengths of straight pipe which would cause the same loss of head, or as decimals or multiples of $v^2/2g$, where v is the mean velocity in the pipe. For any particular special fittings, experiments show that the loss of head is not in all cases a constant fraction of

Table 21—Concluded

Special Losses of Head in Terms of $v^2/2g$

Nature of special resistance	Loss of head as decimal or multiple of $v^2/2g$*
Venturi Meter Tubes	
Venturi meter tubes: the loss of head occurs mostly in and downstreamwards from the divergence, the loss between upstream end and throat being only 0.03 to $0.06 \times v^2/2g$, where v is the throat velocity. The total loss through the meter is:	
For total angle of divergence $= \pm 5$ degrees	$\frac{1}{7}$ to $\frac{1}{10}$ Where v is the throat velocity
For total angle of divergence $= \pm 15$ degrees	$\frac{1}{3}$ to $\frac{1}{6}$
(The lower values go with large throats, and the larger values with small throats whose diameter is from ⅓ to ½ the diameter of the pipe.)	
Sudden Enlargement	
Sudden enlargement, from a small pipe ending abruptly where a larger pipe begins, is found to involve loss of head fairly close in accordance with Borda's Formula which is: $\text{Loss of head} = \frac{(v_1 - v_2)^2}{2g}$ (Note that this is not the difference of the velocity heads, but is the head corresponding to the difference of the velocities.) The above-stated formula may be written: $\text{Loss of head} = \left(1 - \frac{A_1}{A_2}\right)^2 \frac{v_1^2}{2g}$, or for a circular or square pipe: $\text{Loss of head} = \left[1 - \left(\frac{d_1}{d_2}\right)^2\right]^2 \times \frac{v_1^2}{2g}$ where A_1, v_1 and d_1 refer to the smaller upstream pipe, while the subscript 2 refers to the larger downstream pipe.	
Sudden Square-Edged Reductions	
Sudden square-edged reductions in pipes. When the sudden reduction of pipe is very large, say $d_2/d_1 = 0.1$, the loss of head is practically as given for square-edged entry, i.e., loss of head $= 0.40\, v_2^2/2g$. For smaller reductions the value of K is smaller, but the experimental data of Weisbach (1855) and Brightmore (1907) do not agree. For ratios $d_2/d_1 =$ 0.5, 0.75, and 0.9 the value K is about 0.33, 0.20 and 0.08, respectively. In this case the subscript 2 refers to the smaller downstream pipe, and K is the factor which, multiplied by $v_2^2/2g$, gives the loss of head.	

*Note: Except where otherwise noted, the v is mean velocity in the pipe.

$v^2/2g$, but that the fraction varies somewhat with the velocity. For most practical purposes, however, the values given in 21 may be relied on as safe average values.

Water Hammer

When a valve in a water line is closed while the water is flowing, the velocity of the water upstream from the valve is reduced and a dynamic pressure is exerted in addition to the normal static pressure. This dynamic pressure, commonly called "water hammer," is the result of the transformation of the kinetic energy of the moving mass of water into pressure energy which expends itself (unless relief devices are provided) by compressing the water and stretching the pipe walls. When a valve is closed suddenly, the magnitude of the dynamic pressure produced is frequently much greater than the static pressure on the line, and may cause fracture of the pipe or fittings.

Starting at the suddenly-closed valve, a wave of increased pressure is transmitted back through the pipe with constant velocity and intensity. When the pressure wave has traveled upstream to the end of the pipe, where there is a reservoir or large main, the elasticity of the compounded water and of the expanded pipe reverse the flow and a wave of normal pressure travels downstream, the flow being progressively reversed as the water expands.

If the water were incompressible and the pipe inelastic, the instantaneous closure of the valve would create an infinite pressure. Since it is impossible to close a valve instantaneously, it is apparent that a series of pressure waves is created, causing an increased pressure at the valve. If the valve is completely closed before the first pressure wave has time to return to the valves as a wave of low pressure, the pressure increases continually up to the time of complete closure and the resulting pressure is just the same as if the valve had been instantaneously closed. The velocity of the pressure wave depends upon the ratio of wall-thickness to inside pipe diameter and on the modulus of elasticity of the water and of the pipe material according to the formula:

$$S = \frac{12}{\sqrt{\frac{w}{g}\left(\frac{1}{E_w} + \frac{d}{E_p t}\right)}}$$

The head due to water hammer in excess of normal static head is proportional to the destroyed velocity and to the velocity of the pressure wave along the pipe. Since the intensity of the excess head depends upon the destroyed velocity, the same excess pressure is produced by suddenly reducing the velocity from 6 to 3 feet per second, as by entirely stopping a velocity of 3 feet per second. The excess head due to water hammer is given by the formula:

$$h = \frac{12\, v}{g\sqrt{\frac{w}{g}\left(\frac{1}{E_w} + \frac{d}{E_p t}\right)}}$$

where S = Velocity of pressure wave along pipe in feet per second.
w = Weight of water in pounds per cubic foot.
h = Head due to water hammer (in excess of static head).
g = Acceleration of gravity.
t = Wall-thickness of pipe in inches.
d = Inside diameter of pipe in inches.
E_p = Modulus of elasticity of pipe material in pounds per square inch.
E_w = Modulus of elasticity of water in pounds per square inch.
v = Destroyed velocity in feet per second.

By inserting values for g, w, E_w and E_p the two formulas may be simplified. Thus, if
$g = 32.174$ feet per second per second.
$w = 62.4096$ pounds per cubic foot (at 50° F.)
$E_w = 300{,}000$ pounds per square inch.
$E_p = 29{,}000{,}000$ pounds per square inch (for steel pipe)
the formulas reduce to:

$$S = \frac{4720}{\sqrt{1 + .0103\frac{d}{t}}}$$

$$h = \frac{147\, v}{\sqrt{1 + .0103\frac{d}{t}}}$$

If the flow is not checked rapidly, so that the wave from the first movement of the valve has time to travel upstream to the end and back again several times while the valve closing is in progress, the excess pressure is greatly reduced. Therefore, it is advisable to use slow closing valves or to provide air chambers or surge tanks in the line to absorb the shock due to water hammer.

Measurement of Flowing Water

Pitot Tubes

Pitot tubes are used to measure the velocity of flowing water. Such a tube consists essentially of a vertical tube, the lower end of which is bent at 90° so that its open end is directed against the current. The velocity of the flowing water causes the water to rise in the vertical leg of the pitot tube a distance above the free surface of the stream equal to the velocity head.

When a pitot tube is inserted into a pipe carrying water under pressure, the water will rise in the vertical leg of the tube a distance equal to the sum of the pressure head and the velocity head at the point where the tube is inserted. If a piezometer tube is tapped into the wall of the pipe at substantially the same point, the water will rise in this tube a distance equal to the pressure head at that point. The difference in the levels of the water in the two tubes will therefore be equal to the velocity head in the pipe at the point where the tubes are inserted. Fig. 37 shows such an arrangement. The height of the water in the pitot tube is equal to the sum of the pressure head, h_p, and the velocity head, h_v. The height of the water in the piezometer tube is equal to the pressure head, h_p. The

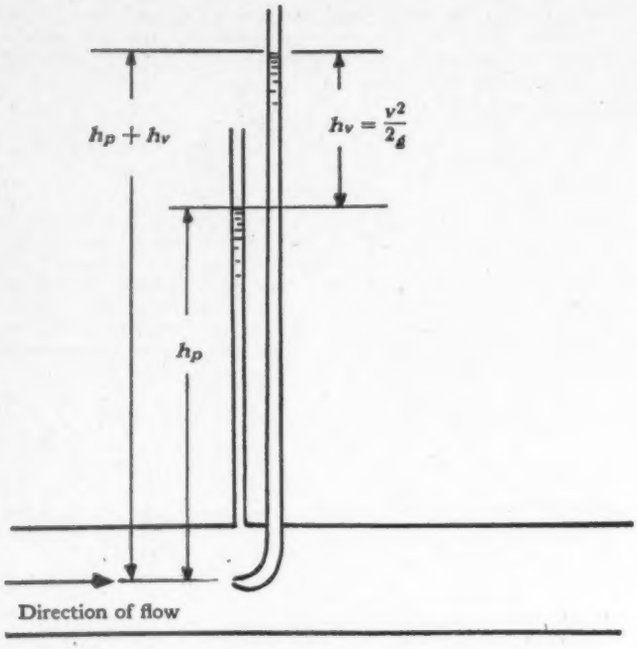

Fig. 37—Pitot Tube

difference in the height of the water in the two tubes is therefore equal to the velocity head, h_v.

Mercury columns or manometers may be used, instead of the water column, to determine the pressures.

In order to determine the discharge by use of a pitot tube, the cross section of the stream or pipe must be divided into one or more known areas, the velocity for each found, and hence the mean velocity of the entire cross section. The discharge is then found by multiplying the cross-sectional area by the mean velocity. In a straight length of pipe which extends upstream about 50 diameters from place of measurement without tees, valves, etc., the distribution of velocities is normal. Where normal distribution of velocities prevails, the ratio of mean velocity to center velocity (called the pipe coefficient) averages about 0.83.

Venturi Meters

The Venturi meter was invented by Clemens Herschel and was named by him for the inventor of the principle involved. It may be used to measure the discharge of water or other fluids contained in pipes which run full and under positive pressure.

The Venturi tube consists of a converging cone of steep taper, a diverging cone of more gradual taper, and a short cylindrical section called the throat, which connects the two cones at their smallest diameters. The essential parts of a Venturi meter are shown in Fig. 38. In this figure h_1 represents the pressure head in the pipe upstream for the Venturi meter, h_2 the pressure head at the throat, and h_3 the pressure head in the pipe downstream from the Venturi meter. The difference between h_1 and h_3 is hf and is the loss of head due to friction in the Venturi tube. The loss of head in a Venturi tube is usually quite small (see Table 21). Where the recovery of pressure is not important the converging cone may be very short or may even be omitted, forming a Venturi nozzle.

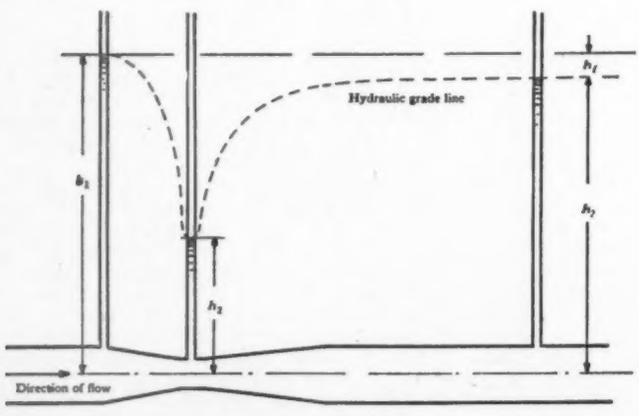

Fig. 38—Venturi Meter

Since the quantity of water flowing past any cross section of the tube is the same at any instant, the velocity at the small cross section of the throat will be greater than in the large cross section of the pipe upstream from the Venturi tube.

This greater velocity in the throat is obtained at the expense of the pressure head, so that h_2 is less than h_1. The dotted line in the figure represents the approximate hydraulic grade line and indicates the loss and recovery of pressure from h_1 to h_3.

The relation between the flow through a Venturi tube and the difference in pressure between the inlet and throat is given by the formula:

$$Q = C_v A_2 \sqrt{\frac{2gh_d}{1-\left(\frac{A_2}{A_1}\right)^2}} = C_v A_2 \sqrt{\frac{2gh_d}{1-\left(\frac{D_2}{D_1}\right)^4}}$$

where Q = Discharge in cubic feet per second.
D_1 = Inside diameter of pipe in feet.
D_2 = Inside diameter of throat of Venturi tube in feet.
A_1 = Cross-sectional area of inside of pipe in square feet.
A_2 = Cross-sectional area of inside of throat of tube in square feet.
g = Acceleration of gravity = 32.174 feet per second per second.
h_d = Differential head in feet of water = $h_1 - h_2$.
C_v = Discharge coefficient of Venturi tube which varies from about 0.95 to 0.995.

The pressure differences ($h_1 - h_2$) may be measured by a simple glass U-tube containing mercury. Commercial Venturi tubes are usually provided with two annular chambers connected by vents with the inlet and throat, respectively, to obtain correct average pressures at these points. Various types of indicating, recording and integrating meters may be obtained for use with commercial Venturi tubes.

Pipe Orifices

Orifices in diaphragms inserted between pairs of flanges in straight portions of pipe lines have been found to be reliable measuring devices. The diaphragms are usually of thin noncorrodible metal and the orifices are accurately machined to size and beveled on the downstream side to keep the working edge thin.

Fig. 39 shows the essential parts of such a device. Two piezometer tubes are attached to the line, one at a distance of

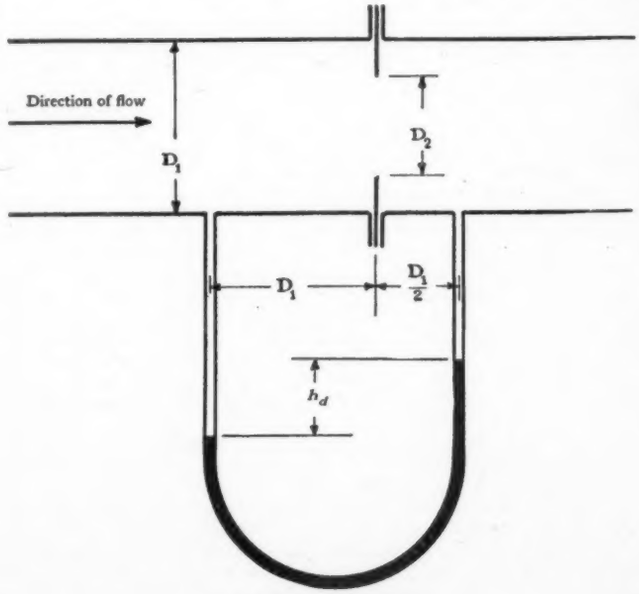

Fig. 39—Pipe Orifice

one pipe diameter upstream and the other one-half pipe diameter downstream from the plate. Either a differential gage, as shown in the figure, or open water columns may be used, depending upon the pressure. The rate of flow is a function of the differential pressure as indicated by the formula:

$$Q = C_o A_2 \sqrt{\frac{2ghd}{1-\left(\frac{A_2}{A_1}\right)^2}} = C_o A_2 \sqrt{\frac{2ghd}{1-\left(\frac{D_2}{D_1}\right)}}$$

where Q = Discharge in cubic feet per second.
D_1 = Inside diameter of pipe in feet.
D_2 = Diameter of orifice in feet.
A_1 = Cross-sectional area of inside of pipe in square feet.
A_2 = Cross-sectional area of orifice in square feet.
g = Acceleration of gravity = 32.174 feet per second per second.
hd = Differential head in feet of water = $h_1 - h_2$.
C_o = Discharge coefficient = about 0.606 for D_2/D_1 from 0.10 to 0.75.

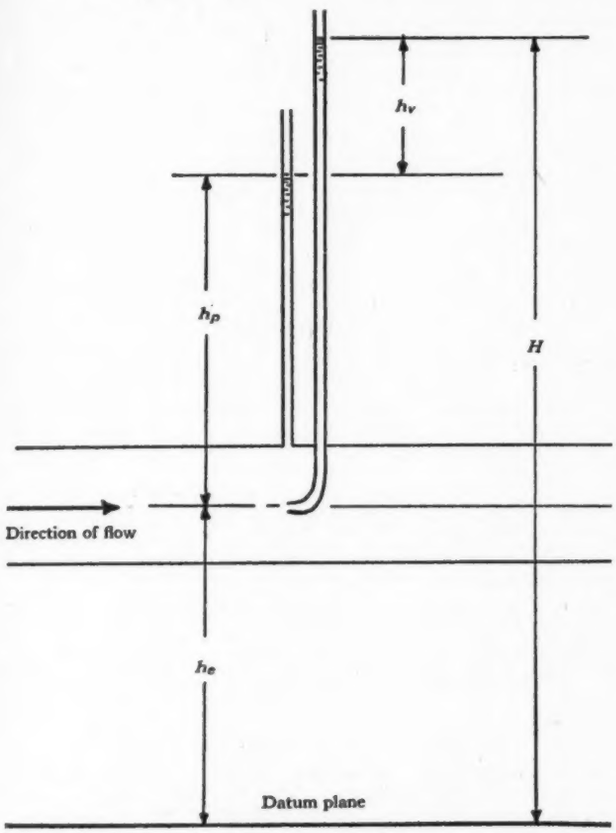

Fig. 40—Total Head

The orifice should be placed in a straight section of horizontal or vertical pipe and should be located as far as possible from bends, fittings, and valves. The diameter of the orifice should not be greater than 75 to 80 per cent of the inside diameter of the pipe. The loss of head in the pipe orifice is quite large and it is less reliable than the Venturi meter.

Water Power

The total available power of flowing water is given by the formula:

$$H.P. = \frac{QwH}{550} = 0.113472\,QH$$

where $H.P.$ = Horse Power.
Q = Discharge in cubic feet per second.
H = Total available head in feet.
w = Weight of one cubic foot of water (at 50° F. = 62.4096 pounds).

The total head may be made up of velocity head, pressure head, and potential head, or head due to actual height above the datum plane. Fig. 40 illustrates the three components of the total head.

The value of the velocity head is given by the expression:

$$h_v = \frac{v^2}{2g}$$

where h_v = Velocity head in feet.
v = Mean velocity in feet per second.
g = Acceleration of gravity = 32.174 feet per second per second.

Table 22
Horsepower for Various Heads of Water

Horse power for 1 cu. ft. of water per second under heads of 1 to 2,000 ft. Based on an efficiency of 80 per cent and weight of water at 50°F. = 62.4096 lb. per cubic foot.

(Horse power per cubic foot of water per second = $\frac{62.4096 \times 0.80 \times H}{550} = 0.0907776\,H$).

Head in feet (*H*)	Horse power	Head in feet (*H*)	Horse power	Head in feet (*H*)	Horse power	Head in feet (*H*)	Horse power
1	0.0907776	170	15.4322	420	38.1266	925	83.9693
2	.181555	180	16.3400	430	39.0344	950	86.2387
3	.272333	190	17.2477	440	39.9421	975	88.5082
4	.363110	200	18.1555	450	40.8499	1000	90.7776
5	.453888	210	19.0633	460	41.7577	1050	95.3165
6	.544666	220	19.9711	470	42.6655	1100	99.8554
7	.635443	230	20.8788	480	43.5732	1150	104.394
8	.726221	240	21.7866	490	44.4810	1200	108.933
9	.816998	250	22.6944	500	45.3888	1250	113.472
10	.907776	260	23.6022	525	47.6582	1300	118.011
20	1.81555	270	24.5100	550	49.9277	1350	122.550
30	2.72333	280	25.4177	575	52.1971	1400	127.089
40	3.63110	290	26.3255	600	54.4666	1450	131.628
50	4.53888	300	27.2333	625	56.7360	1500	136.166
60	5.44666	310	28.1411	650	59.0054	1550	140.705
70	6.35443	320	29.0488	675	61.2749	1600	145.244
80	7.26221	330	29.9566	700	63.5443	1650	149.783
90	8.16998	340	30.8644	725	65.8138	1700	154.322
100	9.07776	350	31.7722	750	68.0832	1750	158.861
110	9.98554	360	32.6799	775	70.3526	1800	163.400
120	10.8933	370	33.5877	800	72.6221	1850	167.939
130	11.8011	380	34.4955	825	74.8915	1900	172.477
140	12.7089	390	35.4033	850	77.1610	1950	177.016
150	13.6166	400	36.3110	875	79.4304	2000	181.555
160	14.5244	410	37.2188	900	81.6998	....	.....

Table 25—Pressure Equivalents

Units		Pounds per square inch	Pounds per square foot	Kilograms per square centimeter	Inches of mercury at 32° F.	Feet of water at 39.2° F.	Feet of water at 62° F.	Atmospheres
1 pound per square inch	=	1.	144.	0.0703067	2.0360	2.30671	2.30934	0.068044
1 pound per square foot	=	0.0069444	1.	0.0004882	0.014139	0.016019	0.016037	0.0004725
1 ounce per square inch	=	0.0625	9.	0.0043942	0.12725	0.144169	0.144334	0.0042528
1 kilogram per square centimeter	=	14.2234	2048.17	1.	28.9582	32.8092	32.8467	0.967820
1 kilogram per square meter	=	0.0014223	0.204817	0.0001	0.0028958	0.0032809	0.0032847	9.678×10^{-5}
1 inch of mercury at 32° F.	=	0.49117	70.7285	0.034533	1.	1.13299	1.13428	0.033421
1 inch of water at 39.2° F.	=	0.036127	5.20222	0.0025399	0.073552	0.083333	0.083428	0.0024582
1 inch of water at 62° F.	=	0.036085	5.19628	0.0025370	0.073468	0.083238	0.083333	0.0024554
1 foot of water at 39.2° F.	=	0.43352	62.4266	0.030479	0.88262	1.	1.00114	0.029498
1 foot of water at 62° F.	=	0.43302	62.3554	0.030444	0.88162	0.99886	1.	0.029465
1 atmosphere	=	14.6963	2116.27	1.03325	29.9210	33.9001	33.9388	1.

Table 26—Rate of Flow Equivalents

Units		Cubic feet per second	Cubic feet per minute	U. S. gallons per minute	U. S. gallons per 24 hours	British Imperial gallons per minute	Liters per minute	Acre-feet per hour	Acre-feet per 24 hours
1 cubic foot per second	=	1.	60.	448.831	646 317.	373.729	1698.98	0.082645	1.98347
1 cubic foot per minute	=	0.016667	1.	7.48052	10 771.9	6.22882	28.3163	0.0013774	0.033058
1 U. S. gallon per minute	=	0.0022280	0.13368	1.	1440.	0.83267	3.78533	0.0001841	0.0044192
1 U. S. gallon per 24 hours	=	1.547×10^{-6}	9.283×10^{-5}	0.0006944	1.	0.0005782	0.0026287	1.279×10^{-7}	3.069×10^{-6}
1 British Imperial gallon per minute	=	0.0026757	0.16054	1.20095	1729.37	1.	4.54601	0.0002211	0.0053072
1 liter per minute	=	0.0005886	0.035315	0.26418	380.416	0.21997	1.	4.864×10^{-5}	0.001167
1 acre-foot per hour	=	12.1	726.	5430.86	7 820 434.	4522.13	20 557.6	1.	24.
1 acre-foot per 24 hours	=	0.50417	30.25	226.286	325 851.	188.422	856.567	0.041667	1.

Table 26—Volume and Capacity Equivalents

Units		United States gallons	British Imperial gallons	Liters	Cubic feet	Cubic inches	Acre-feet
1 United States gallon	=	1.	0.832672	3.78533	0.133681	231.	3.069×10^{-6}
1 British Imperial gallon	=	1.20095	1.	4.54601	0.160544	277.420	3.686×10^{-6}
1 liter	=	0.264177	0.219973	1.	0.035315	61.0250	8.107×10^{-7}
1 cubic foot	=	7.48052	6.22882	28.3163	1.	1728.	2.296×10^{-5}
1 cubic inch	=	4.329×10^{-3}	3.605×10^{-3}	0.016387	5.787×10^{-4}	1.	1.329×10^{-8}
1 acre-foot	=	325 851.	271 328.	1 233 456.	43 560.	75 271 680.	1.
1 inch deep on 1 acre	=	27 154.3	22 610.6	102 788.	3 630.	6 272 640.	0.083333
1 inch deep on 1 square mile	=	17 378 743.	14 470 801.	65 784 344.	2 323 200.	4 014 489 600.	53.3333
1 meter deep on 1 hectare	=	2 641 705.	2 199 675.	9 999 734.	353 145.	610 233 780.	8.10708
1 centimeter deep on 1 square meter	=	2.64171	2.19967	9.99973	0.353145	610.234	8.107×10^{-6}
1 pound of water at 39.2° F.	=	0.11983	0.099778	0.45359	0.016019	27.6805	3.677×10^{-7}
1 pound of water at 50° F.	=	0.11986	0.099806	0.45372	0.016023	27.6880	3.678×10^{-7}
1 pound of water at 62° F.	=	0.11997	0.099892	0.45411	0.016037	27.7121	3.682×10^{-7}
1 U. S. gallon per minute for 24 hours	=	1440.	1199.05	5450.88	192.5	332 640.	0.0044192
1 cubic foot per minute for 24 hours	=	10 771.9	8 969.50	40 775.4	1440.	2 488 320.	0.033058

The pressure head is given by the expression:

$$h_p = \frac{P}{w}$$

where h_p = Pressure head in feet.

P = Pressure in pounds per square foot.

The potential head or head due to height above the datum plane is h_e feet.

The total head, H, is therefore:

$$H = h_v + h_p + h_e$$

or

$$H = \frac{v_2}{2g} + \frac{P}{w} + h_e$$

In any stream flowing steadily without friction, the total head, and the total amount of energy per unit of water, is the same at every point in the path of flow. This principle, which is in reality the law of conservation of energy applied to flowing water, is known as Bernoulli's Theorem.

Table 22 gives the horse power for one cubic foot of water per second, under heads of 1 to 2000 feet, based on an efficiency of 80 per cent. The method of using this table is illustrated by the following example:

Determine the horse power which can be developed by a flow of 60 cubic feet per second under a head of 200 feet.

From the table the horse power for a discharge of one cubic foot per second under 200 feet head is found to be 18.1555. The horse power for a discharge of 60 cubic feet per second under 200 feet head is then:

$$60 \times 18.1555 = 1089.33 \text{ horse power.}$$

When the exact head is not given in the table the horse power may be found by multiplying the horse power for one foot head and one cubic foot per second (0.0907776) by the head in feet and then by the discharge in cubic feet per second. For example, the horse power which can be developed by a discharge of 45 cubic feet per second under a head of 105 feet will be:

$$0.0907776 \times 105 \times 45 = 428.92 \text{ horse power.}$$

PRACTICAL HYDRAULICS*

By P. S. WILSON†
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I. The Sharp Crest Weir

The so called Sharp Crest Weir is a very useful device for the measurement of water flowing in open channels or streams. A knowledge of the few simple rules governing the design and use of weirs will make it possible to measure the flow of water shed streams contributing to reservoirs, to estimate the overflow or leakage of dams and to make other measurements of use to the water works operator.

By a Weir is meant a bulkhead or dam over which the water flows, or more particularly, a notch in the top of such a structure through which the water flows. As shown in the illustration (Fig. 1), it usually consists of a rectangular notch and it is then known as a Rectangular Weir.

The Crest of a weir is the bottom of the notch, the level to which the water must rise before any can flow over. It is the edge or sill over which the water flows. A weir is a Sharp Crest Weir when the bottom edge of the notch, or the crest, is constructed so as to be as sharp as possible, flush with the upstream face of the dam, and with the opening beveled or enlarged on the downstream side so that the stream of water as it passes through the opening will only touch the crest along one sharp edge, as shown in Fig. 2. In the laboratory the crest is kept as sharp as a knife edge. In practice the edge of a metal plate or angle iron, as shown in the illustration, is usually satisfactory unless extreme accuracy is desired. The upstream face of the weir should be vertical, and of course the crest should be exactly horizontal.

The Head on a weir is the difference in elevation between the crest of the weir and the surface of the water in the pool upstream from the weir. With any given weir there is a fixed relation between the head and the amount of water being discharged, thus by measuring the head the discharge may be determined from the formula or table which applies to that particular form of weir in use.

The relation between the head and the discharge of a weir is different with different forms of crest and different shapes of notches. Different formulas must be used with such different weirs. The reason for making a weir sharp crested is that by so doing a weir can be built which can be used for the measurement of water without the necessity for making special tests to determine what the formula is. The formula for rectangular sharp crest weirs is known, and it has been found easier to reproduce standard conditions by the use of the sharp crest design than with most other forms. Most weirs built for the measurement of water are therefore constructed as sharp crest weirs.

Weir Formulas

One of the most commonly used formulas for use with rectangular sharp crest weirs is known as the Francis formula, named for its originator, Mr. J. B. Francis, who performed extensive experiments on weirs at Lowell, Mass., in 1851. This formula is as follows:

$$Q = 3.33 \times L \times h \times \sqrt{h}$$

In this formula:—

Q = Discharge of the weir in cubic feet per second.
L = Length of the weir crest in feet.
h = Head on the weir in feet.
$\sqrt{h}$ = The square root of the head in feet. The square root of the head is the number which, multiplied by itself, equals the head.

($h \times \sqrt{h}$ is often expressed as $h^3/^2$, but it is more readily computed if considered in the form given above.)

Example: A sharp crest rectangular weir is 5.00 feet long and has a head of 0.42 feet (5 inches) on it.

(The square root of 0.42 is 0.65, because $0.65 \times 0.65 = 0.42$.)

$Q = 3.33 \times 5.00 \times 0.42 \times 0.65 = 4.55$ cu. ft. per second.

The Francis formula given above is most accurate for heads between about 0.30 feet and 2.00 feet. A small error in determining the head makes such a large error in the discharge at very low heads, that for most practical purposes this formula is sufficiently accurate at all heads up to about 2.00 feet, and it is fairly accurate for higher heads also. The great advantage of the Francis formula is the fact that it is much simpler to compute than most of the others. The principal other formulas are known as the Bazin formula, the Fteley and Stearns formula and the Rehbock formula. A complete treatise may be referred to for the details of these other formulas.

For convenience the results of the computations from a weir formula may be arranged in a table, as shown in Table I. The discharge read from the table may be multiplied by the length (in feet) of any sharp crest weir to obtain the discharge.

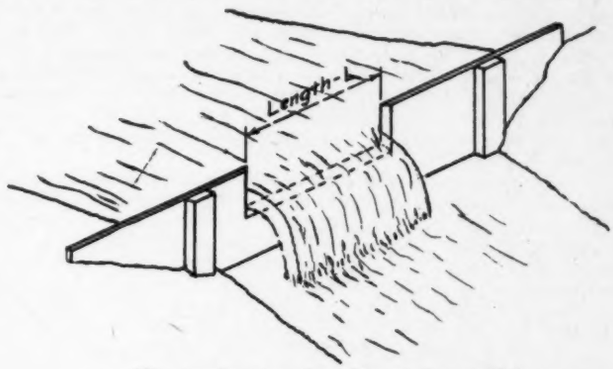


Fig. 1—Rectangular Sharp Crest Weir

TABLE I—DISCHARGE OF A SHARP CREST WEIR PER FOOT OF LENGTH BY THE FRANCIS FORMULA

Head Expressed in Feet	Head Expressed in Inches	Discharge per Foot of Length of Weir Expressed in Cubic Feet per Second	Discharge per Foot of Length of Weir Expressed in Gallons per Minute
.01	1/8	.0033	1.5
.02	1/4	.0094	4.2
.03	3/8	.0173	7.8
.04	1/2	.0266	11.9
.05	5/8	.0372	16.7
.06	3/4	.049	22.0
.07	7/8	.062	27.7
.08	1	.075	33.8
.09	1 1/8	.090	40.4
.10	1 1/4	.105	47.2
.12	1 1/2	.138	62.
.14	1 5/8	.175	78.
.16	1 7/8	.213	96.
.18	2 1/8	.254	114.
.20	2 3/8	.298	134.
.22	2 5/8	.344	155.
.24	2 7/8	.392	176.
.26	3 1/8	.441	198.
.28	3 3/8	.49	222.
.30	3 5/8	.55	246.
.32	3 7/8	.60	271.
.34	4 1/8	.66	296.
.36	4 3/8	.72	323.
.38	4 1/2	.78	350.
.40	4 3/4	.84	378.
.42	5	.91	407.
.44	5 1/4	.97	436.
.46	5 1/2	1.04	467.
.48	5 3/4	1.11	497.
.50	6	1.18	530.
.55	6 5/8	1.36	610.
.60	7 1/4	1.55	690.
.65	7 3/4	1.75	780.
.70	8 3/8	1.95	870.
.75	9	2.16	970.
.80	9 5/8	2.38	1070.
.85	10 1/4	2.61	1170.
.90	10 3/4	2.84	1270.
.95	11 3/8	3.08	1380.
1.00	12	3.33	1500.

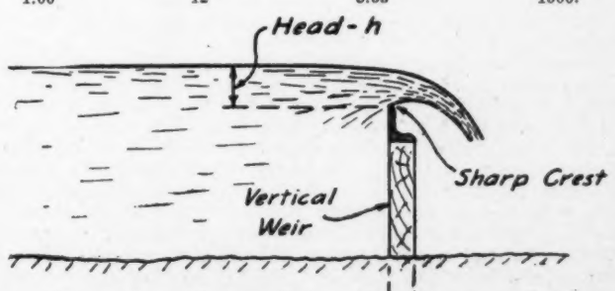


Fig. 2—Cross Section Rectangular Sharp Crest Weir

(Continued on page 364)

*From WATER WORKS AND SEWERAGE.
†Asst. Secy., American Water Works Assn.

II. The End Contractions of a Weir

There are two methods of constructing the ends of the weir. The first of these is shown in Fig. 3 and results in what is known as a weir *with end contractions.* In this design the sharp crest of the weir as formed by the bottom of the notch is continued up the ends of the notch, thus forming sharp edged ends for the weir. The water in flowing around these sharp corners then follows a course very similar to that taken in flowing over the edge of a sharp crest. In flowing around the edge from behind the weir it cannot change direction sharply and it curves inward toward the center of the weir contracting the stream as shown in the illustration.

The other method of designing the ends of the notch is to build it so that it extends the full width of the stream at that point, allowing the sides of the channel to form the ends of the notch and continue upstream at that width for a short distance, at least. An example of this method of construction is shown in Fig. 4. When so built it is known as a weir *without end contractions* because the water in this case flows straight over the crest, the stream continuing full width all the way. The weir thus consists of a simple dam or bulkhead across the channel.

It may readily be seen that if two rectangular sharp crest weirs have the same length and are flowing under the same head, the one that has end contractions (Fig. 3) is not discharging as much water as the weir without end contractions (Fig. 4). It has been found by experimentation that with sharp edged ends and a wide channel above the weir, so that the over-falling stream is fully contracted, the effect on the discharge of the weir is the same as if the length of the weir were reduced by a distance equal to one-tenth (0.1) of the head at each end of the weir.

For example: A sharp crested, rectangular, vertical weir is three feet long and the ends are so constructed that the flow will be fully contracted. If the head is one foot, then the effective length of the weir is reduced by one-tenth of a foot at each end making its effective length (3.0 — O.z) = 2.8 feet—a reduction in capacity of about 7 per cent from the capacity it would have had without end contractions. Failure to make this correction might constitute a rather serious error.

If the head on the same 3 foot weir were only 0.1 foot instead of 1.0 foot (or if the length of the weir were increased to 30 feet with a head of 1.0 feet) then in either case the reduction in effective length would be only about 0.7 per cent which

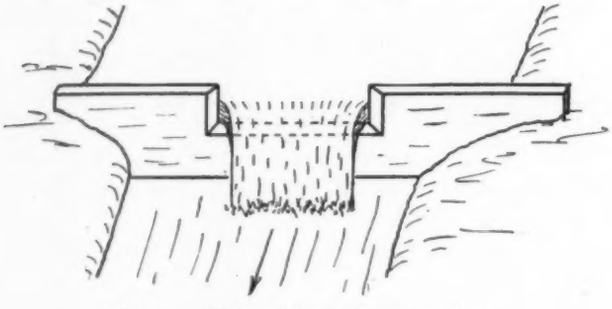


Fig. 3—Weir with End Contractions

would be a negligible error except in the most precise measurements.

It is thus seen that the importance of making the correction for end contractions depends upon the relative head and the length of the weir. If the head is more than one twentieth (5 per cent) of the length then end contractions will require a correction of more than 1 per cent and should certainly be accounted for.

Weirs are seldom operated in practice under a head sufficiently great in proportion to the length that the correction for end contractions is of importance. In such cases it is evident that it does not matter how the ends of the weir are built. Many weirs under practical conditions are built so that they do not have theoretically sharp edged ends and yet neither are they ended against the sides of the stream channel. The ends may merely be formed by the wood or masonry of which the dam bulkhead is built. In such cases we know that there is some end contraction but we do not know how much. Such a weir should be checked up to determine whether the end contraction correction would be of importance if it were complete. If it is found that the relation between the maximum head and the length of the weir is such that the correction would not be

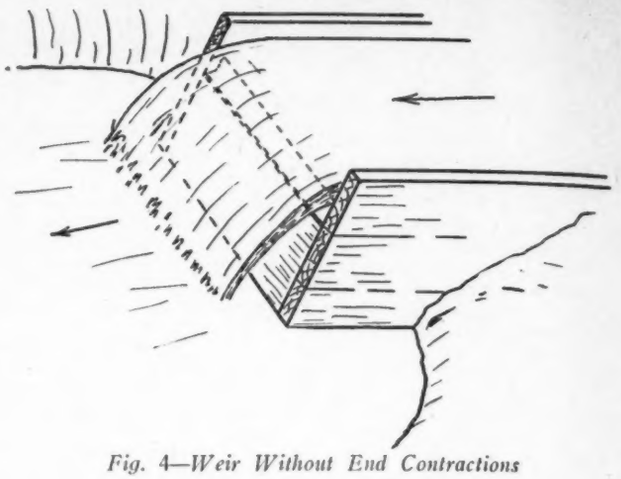


Fig. 4—Weir Without End Contractions

of importance (less than 1 per cent), then we know that it does not matter what it actually is and it can be neglected. It is found that the end contraction correction is of importance then either it must be estimated or else actual measurements of the flow must be made to determine what the correction actually should be. Usually it can be estimated. It is a help in estimating to actually observe the form of the stream during discharge of the weir.

If the relation between the length of the weir and the head is to be such that the end contraction correction will be of importance then the weir should, if possible, be built either with full contractions or with none at all so that the correction will be definitely known.

A weir may be built with a sharp edge on one end only so that the end has a full contraction and so that the other end has no contraction. The correction in such a case is, of course, only one-tenth of the head to be subtracted from the weir length.

III. Measurement of Head on Weirs

The measurement of flowing water by means of a weir depends in turn upon the measurement of the *head* of water on the weir. Having determined the weir formula to be used, depending upon the design of the weir crest, the presence or absence of end contractions and any other fixed condition, the recorded flow then depends upon the head. The head is the single remaining variable quantity. It is the quantity which is actually observed and measured in the field, the desired knowledge as to the amount of water flowing being then computed by the use of the formula, table or diagram. It is assumed in this discussion that the flow over the weir is not affected by backwater from below.

The head on a weir is the difference in elevation between the crest of the weir and the surface of the water in the pool upstream from the weir. Figure 1 is a vertical cross section through a sharp crest weir with water flowing over it under a head indicated by (h). The shape of the upper and lower water surfaces shown in this figure have been determined by measurement and have been found to have forms similar to these, regardless of what the head is, so long as the weir has a sharp crest and a vertical upstream face. Under special conditions at low heads the water may, however, cling to the downstream face of the weir.

Figure 1 shows clearly the fact that in this general case the

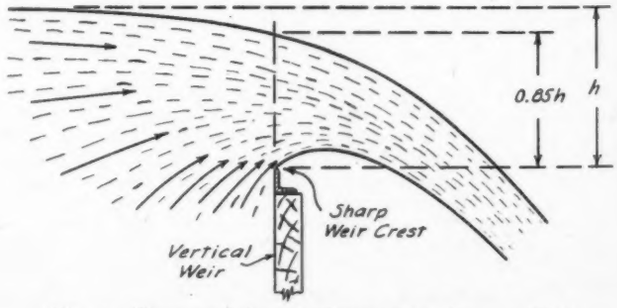


Fig. 1—Characteristics of Water Flow Over a Weir

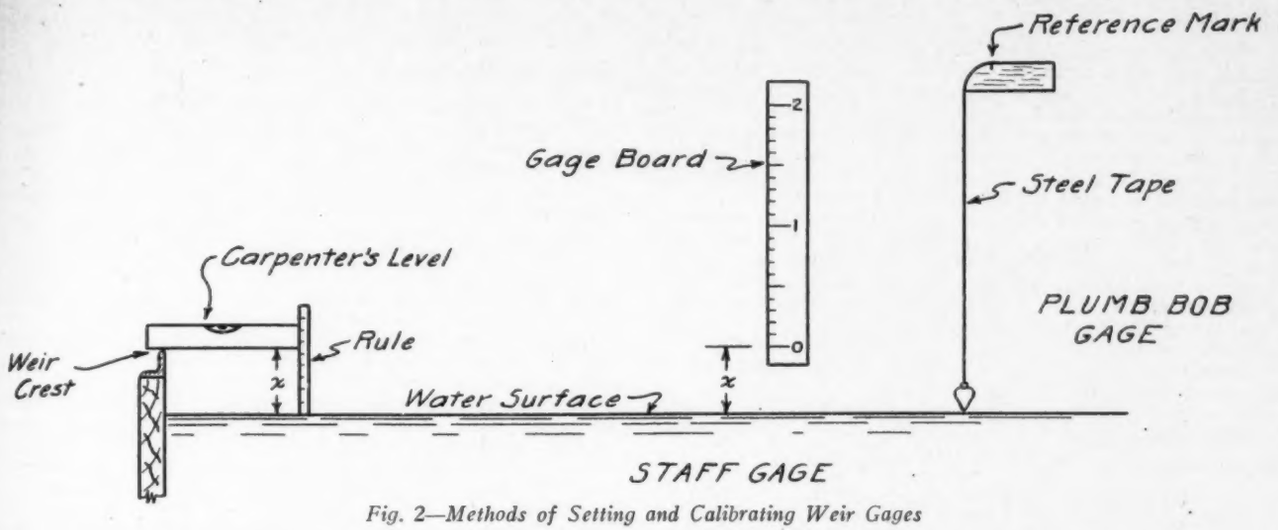


Fig. 2—Methods of Setting and Calibrating Weir Gages

water only touches the crest along the one sharp edge and then leaps free. The arrows showing the converging stream indicate the reason for the shape which the lower surface of the water is found to take. There is one very important fact to be noted from Figure 1—namely, the upper surface of the water starts to curve downward before it reaches the weir. This results in the depth of water at the weir crest actually being only about 85/100ths of "h" (expressed as 0.85h)—the condition which makes it necessary to measure the height of the water surface at some distance upstream from the weir when determining the head. The height of the water surface should be measured at a point located upstream from the weir *a distance at least equal to three times the maximum head* to be encountered.

Measuring Gages

The type and design of gage to be used to determine the water level depends upon the accuracy desired and the conditions under which it will operate.

The Staff-Gage

The simplest and most commonly used type of gage consists merely of a strip of wood or metal with the necessary graduations marked upon it. A section of a carpenter's rule or a surveyor's rod may be used if adequately waterproofed by varnishing. One of the best forms of gage board consists of a vitreous enameled ware metal plate mounted on a wood plank. The graduations and figures are baked into the enamel. Gages such as these, often called staff-gages, if well graduated and carefully read will enable the water level to be determined to within about 0.01 feet, equivalent to about ⅛ inch. This is sufficiently accurate for most purposes other than studies requiring laboratory refinements. One of the greatest disadvantages of this type of gage, however, is the necessity for locating the observer's eye near the water level when taking a reading. This is not always convenient. Care must be taken to read at the true water surface and not the height to which the water surface curves upwards where it wets the gage.

When mounting a staff-gage great care is needed to insure that the zero of the gage is exactly level with the crest of the weir and that it remains so. A small error in this respect will cause a large error in the results, particularly at low heads. Moreover, this error will always be in the same direction and will not tend to correct itself or be compensated for by other errors.

By the careful use of a surveyor's level a gage may be set with sufficient accuracy. If a surveyor's level is not available then the water surface itself may be used in the manner indicated in Figure 2. Choose a time when the water surface is not rising or falling too rapidly and preferably when it is lower than the weir crest. By means of a carpenter's hand level and rule measure the distance (x) down to the water surface from the weir crest. Then measure up from the water surface at the gage location and set the gage zero the same distance (x) above the water level as the weir crest was found to be. Then, afterward, such gages should be regularly checked to be certain that they have not been moved, and that the zero point is correct.

Plumb-Bob Gage

Another form of gage is known as a plumb-bob gage. It consists of a graduated steel tape with a heavy plumb bob on its end. It is used to measure from a fixed reference mark, above water level, down to the water surface. By allowing it to swing slightly the contact of the plumb bob with the water surface may be very accurately noted. This naturally assumes the water surface to be smooth. The plumb-bob gage may be most accurately read if the tape is run over a curved block of wood, mounted permanently above the water, which has the reference mark fixed on its upper surface, as indicated in Figure 2. The zero reading on this type of gage may be determined by measuring down to the water surface from the weir crest as shown in Figure 2 and applying the correction factor determined by a simultaneous reading of the tape.

Chain Gage

A similar type of gage known as a chain gage is often used. For the tape a chain running over a wheel is substituted. With this arrangement the position of a marker attached to the chain above the wheel is read along a horizontal scale. This type of gage is not so accurate as the former and it is not advised for weir readings except in the case of rough work or high heads. It is often used for river heights where accuracy within about 0.05 feet is generally satisfactory.

With all types of gages difficulty is introduced if the water level is disturbed by waves or surges. In the case of the gages above described this can only be overcome by the skill and patience of the operator in mentally averaging the indications while observing them over a short period. Practice can develop considerable skill in doing this.

IV. The Float Gage

Probably the most accurate type of gage, if well designed and constructed, is a float gage. Besides its accuracy it also has other advantages. Difficulty in reading due to waves and surges may be most readily overcome with the float type gage which is readily adapted to the use of an automatic recording mechanism. They may be classified into two types. The simplest type consists of the float with a rigid vertical stem attached to and supported by the float, with an index or pointer at its upper end. The gage reading is obtained from the position of this pointer along a fixed vertical scale. In the other type of float gage the motion of the float is transmitted to some form of indicating or recording mechanism by means of a flexible wire or tape.

The Float

A suitable float is the first essential. It must not become water logged, but must retain its buoyancy. To meet this condition a hollow sheet metal float is generally used, and copper is the preferred material because of its resistance to corrosion. The seams must be well locked and thoroughly soldered. Earthenware floats have been used in sewage or other corrosive liquids. Floats are most often made cylindrical with the axis vertical, in order to fit in a float pipe and for ease of construction. It is important to have the top and bottom dished outward so that the float cannot be weighted with water on top or lifted by air trapped beneath. The float should have at least three vertical fins projecting a half inch or more from its sides in order to prevent it from clinging to the wall of the float pipe or well. Sometimes a spherical float is used, but in that case its weight, or its counterweight, should be adjusted so that it will float near its middle, in order to gain the maximum sensitivity.

Float Pipe

Floats are usually provided with some form of float pipe or stilling well. This serves two principal purposes—it serves as a guide for the float, and by adjusting the size of the communicating opening into the float pipe the effect of waves or surges upon the gage readings may be reduced. The use of a float pipe also makes it possible to locate the gage a short distance away from the body of water being observed, the level in the float pipe being maintained by a small size connecting pipe. With such an arrangement care must be exercised to avoid air traps in the connecting pipe. The connecting pipe should be made of non-corrosive material and should be provided with convenient means for flushing it out. A float pipe should be provided with a cover, having only a small opening for the wire or tape, in order to prevent objects from falling in and lodging on the float.

If the gage mechanism is light and easily operated, a 5-in. diameter float in a 6-in. float pipe makes a good combination. If a high degree of sensitivity is desired, or if a recorder requiring some power to operate it is used, then a larger float is desirable, a 10-in. float in a 12-in. pipe, or even larger, being often used.

Gage With Rigid Stem

The type of float gage having a rigid stem is the simplest and is also probably capable of the closest reading with accuracy, since the only friction involved in its motion is due to whatever guides may be needed to keep the stem upright and in the correct position with relation to the scale. The effect of this friction in preventing accurate response of the gage to changes in the water level may be largely if not entirely avoided by gently tapping the stem while reading the gage. Gages of this type, if properly designed and constructed, may be read directly to the nearest one thousandth of a foot (0.001 ft.), which is about the best in true accuracy that can be expected from single readings of any type of gage.

An arrangement of this type of gage, which has been used extensively and which is highly suitable for accurate weir head readings, is shown in Fig. 1. In this design a 7-in. float may be used in an 8-in. float pipe. The float stem is a brass rod of about 3/16 in. or ¼ in. diameter, depending on the height. The best scale is made from a graduated brass strip about ⅛ in. thick. It is provided with a continuous projection along its back edge which serves to guide the index or pointer in the correct position for easy reading, and to hold the stem vertically above the float.

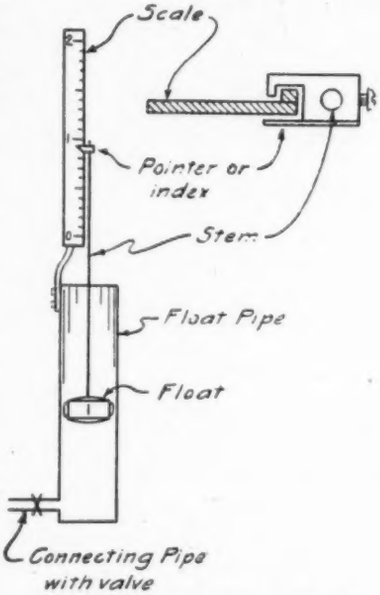


Fig. 1—Float Gage with Stem

Gage With Flexible Wire

The second type of float gage, using a flexible wire or tape, is more adaptable to different arrangements, since the motion is usually converted into a rotary motion by the wheel or drum on which the wire is wound, and thus the readings may be shown on a circular dial, or a recording mechanism may be operated. It is not always so simple to overcome the friction of motion in this type of gage, and for that reason it may not be read quite so accurately unless the float is larger than with the rigid stem type.

A metal wire or tape is necessary for accurate readings in order to avoid changes in length due to stretching or moisture. The wire should be stranded, made from a large number of very small wires braided together, in order to be flexible and withstand frequent bending. Either wire or tape must be of bronze or other non-rusting metal.

The simplest arrangement of this type of gage consists merely of passing the wire over a wheel or pulley and having a counterweight on the end. Reading may then be taken from the motion of a pointer attached to the wire along a fixed vertical scale beside it. A very crude form of such a gage has often been seen on railroad water tanks.

A more usual arrangement in water works practice is to attach the end of the float wire to a drum, around which it is then wound a number of turns. The counterweight is then hung from another wire similarly attached to the drum. By such design slipping of the wire is avoided and the revolution of the drum is a true measure of the change in water level. The drum is then connected to a rotating pointer on a dial or to a recording device. By introducing suitable gearing a wide range of float motion may be shown as only a part of a revolution of the pointer on the dial, or other variations may be introduced changing the scale of readings to suit the conditions and the requirements.

The drum upon which the wire is wound should be provided with spiral grooves to receive the wire so that it will be guided in a single layer and will not wind upon itself, thereby changing the effective diameter of the drum and affecting the accuracy of the gage. If desired, the drum receiving the counterweight wire may be smaller than the drum for the float wire, thereby resulting in a shorter travel for the counterweight where this is of any advantage. The counterweight should not become submerged, since its effective weight would thereby be altered and the submersion of the float changed.

Gage With Tape

If a tape is used it is customary to provide it with uniformly spaced perforations which fall over similarly spaced projecting pins on the drum, thereby preventing slipping. A tape is, of course, not wound around the drum, but merely passes over it once, with the counterweight on the end. The counterweight must then travel through the same range of motion that the float does.

Indicators and Recorders

Many good designs of indicating and recording instruments are commercialy available for use with floats and which are adaptable to different conditions and requirements. Floats may also be utilized similarly to operate transmitters for long distance electrical transmission of gage readings, known as telemeters.

METERING OF WATER AND SEWAGE

By L. D. CARLYON, M.E.
Cleveland, Ohio

PART I—PRIMARY ELEMENTS

In modern sewage plants and water works, metering equipment is now recognized for the important part it plays in obtaining efficient control and operation.

Regardless of type, large meters and registering devices depend upon the so-called "Venturi" principle for their operation. This consists of producing a differential pressure which varies in a definite and known relation to the rate of flow. The differential pressure is mechanically converted into terms of weight or volume and is so indicated and recorded by registering equipment. The actual registers themselves are constructed to provide various combinations of indicating, recording, and totalizing features.

There are three commonly used devices, which can be inserted in fluid lines to produce the desired differential pressure. These are the Venturi tube, the flow nozzle, and the thin plate orifice. Each provides a reduction of the area through which the flow takes place, thereby causing an increase in velocity at this point with a corresponding localized reduction in pressure. The result is a differential in pressure between two areas of the Venturi tube, or on either side of the flow nozzle or orifice inserted in the pipe. Figure 4 illustrates the head differentials created by an orifice insert.

For a given installation the primary element is designed and constructed so that when the maximum rate of flow occurs, a definite maximum head differential will be produced. This varies from a water differential of less than 10 inches to one of more than 200 inches, dependent upon the fluid to be measured, the static pressure, the maximum capacity and the type of register.

Although any one of the three primary elements (Venturi, flow nozzle, or plate orifice) can normally be used, there will usually be one of the three which is best suited to meet the existing requirements. The selection is determined by a number of factors. These factors are to be dealt with in this article, with a view of better acquainting engineers, superintendents or operators with the more important considerations in selection of metering devices. It is hoped that some of the confusion concerning these devices which exists in the minds of some will be cleared away by the following discussion.

Fundamental Comparisons

The Venturi Tube

The Venturi tube has been used for years in connection with projects of the hydraulic and sanitary engineer. As illustrated in Fig. 1, it is designed with a short cylindrical section at the inlet end of the tube, which is cast smooth inside. The high pressure connection is made at this point into the piezometer ring (Fig. 1, Section AA).

*Mechanical Engineer, Bailey Meter Co.

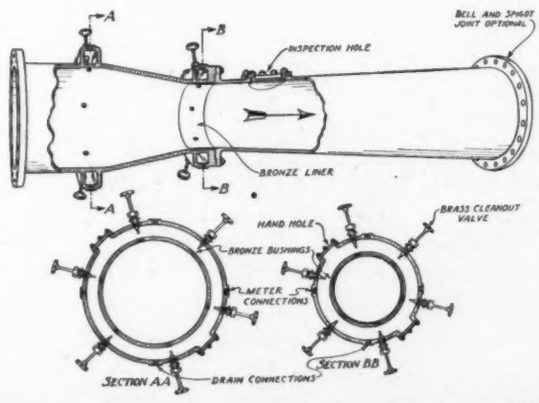


Fig. 1—Venturi Tube. (Handholes and Cleanout Valves Are Used Only for Measurement of Screened Sewage or Sewage Sludges)

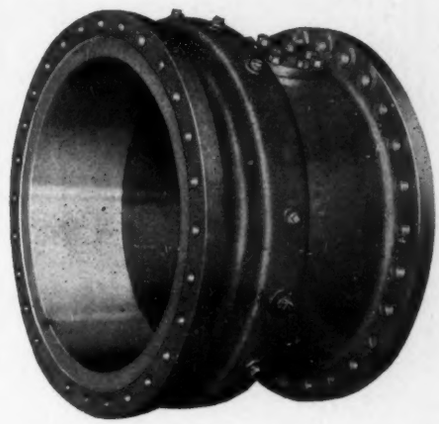


Fig. 2—Venturi Throat Section for a 56-Inch Line, Constructed of Cast Iron with a Machined Bronze Liner

Following the inlet section is an entrance cone of about 21 degrees total angle, which leads to the short cylindrical throat section where the low pressure connection to the meter is made through another piezometer ring. At the throat the tube is flanged, and has a handhole which permits inspection of the throat and piezometer holes, as well as accurate measurement of the throat diameter. An exit cone, known as the diffuser, follows the throat and has a total angle of approximately 5 degrees. This ends in a flange for connecting the tube to the pipe line flange.

In certain cases due to objection to the laying length of the long Venturi tube or possibly for reasons of cost, a tube referred to as a "short Venturi" is used. It differs from the long tube primarily in that the angle of the exit cone is much greater (normally 13 to 15 degrees total angle), thus making the overall length much less than a long tube of corresponding diameter which is justified on the grounds that a smaller head loss is created.

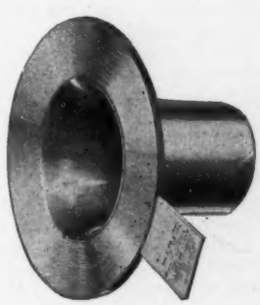


Fig. 3—Flow Nozzle

The majority of Venturi tubes are fabricated of cast iron and are provided with brass or bronze liners in the throat which are machined smooth within close tolerances. Small tubes of from 1 to 2 inches diameter are often made of brass or bronze throughout and the entire length of the internal surface may be completely machined all over. Very large ones have been constructed of concrete or steel plate with a cast iron throat section having a machined bronze liner, such as shown in Fig. 2.

Flow Nozzle

In many respects the flow nozzle (Fig. 3) may be considered to be a simplified Venturi tube. The entrance consists of a gradual curve of approximately one-quarter ellipse which leads the fluid smoothly into a short cylindrical throat section. Thus the discharge jet will have no contraction and will be the same diameter as the throat itself.

Installation of the flow nozzle is made by inserting it between a pair of pipe flanges. The high pressure upstream connection is usually made by tapping the pipe line approximately 1 pipe diameter back of these flanges, and the low pressure connection is made on the line at a point just opposite the throat section of the nozzle. For the measurement of water, air, sewage or

Float Pipe

Floats are usually provided with some form of float pipe or stilling well. This serves two principal purposes—it serves as a guide for the float, and by adjusting the size of the communicating opening into the float pipe the effect of waves or surges upon the gage readings may be reduced. The use of a float pipe also makes it possible to locate the gage a short distance away from the body of water being observed, the level in the float pipe being maintained by a small size connecting pipe. With such an arrangement care must be exercised to avoid air traps in the connecting pipe. The connecting pipe should be made of non-corrosive material and should be provided with convenient means for flushing it out. A float pipe should be provided with a cover, having only a small opening for the wire or tape, in order to prevent objects from falling in and lodging on the float.

If the gage mechanism is light and easily operated, a 5-in. diameter float in a 6-in. float pipe makes a good combination. If a high degree of sensitivity is desired, or if a recorder requiring some power to operate it is used, then a larger float is desirable, a 10-in. float in a 12-in. pipe, or even larger, being often used.

Gage With Rigid Stem

The type of float gage having a rigid stem is the simplest and is also probably capable of the closest reading with accuracy, since the only friction involved in its motion is due to whatever guides may be needed to keep the stem upright and in the correct position with relation to the scale. The effect of this friction in preventing accurate response of the gage to changes in the water level may be largely if not entirely avoided by gently tapping the stem while reading the gage. Gages of this type, if properly designed and constructed, may be read directly to the nearest one thousandth of a foot (0.001 ft.), which is about the best in true accuracy that can be expected from single readings of any type of gage.

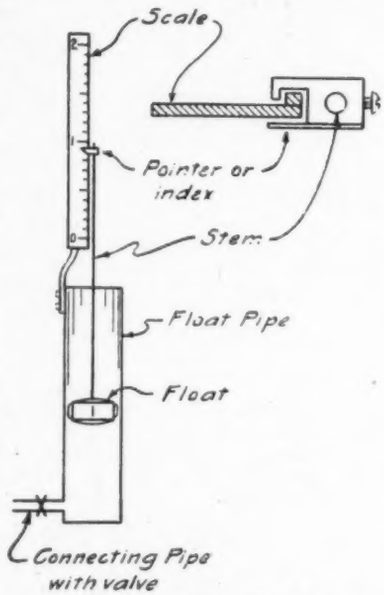


Fig. 1—Float Gage with Stem

An arrangement of this type of gage, which has been used extensively and which is highly suitable for accurate weir head readings, is shown in Fig. 1. In this design a 7-in. float may be used in an 8-in. float pipe. The float stem is a brass rod of about 3/16 in. or ¼ in. diameter, depending on the height. The best scale is made from a graduated brass strip about ⅛ in. thick. It is provided with a continuous projection along its back edge which serves to guide the index or pointer in the correct position for easy reading, and to hold the stem vertically above the float.

Gage With Flexible Wire

The second type of float gage, using a flexible wire or tape, is more adaptable to different arrangements, since the motion is usually converted into a rotary motion by the wheel or drum on which the wire is wound, and thus the readings may be shown on a circular dial, or a recording mechanism may be operated. It is not always so simple to overcome the friction of motion in this type of gage, and for that reason it may not be read quite so accurately unless the float is larger than with the rigid stem type.

A metal wire or tape is necessary for accurate readings in order to avoid changes in length due to stretching or moisture. The wire should be stranded, made from a large number of very small wires braided together, in order to be flexible and withstand frequent bending. Either wire or tape must be of bronze or other non-rusting metal.

The simplest arrangement of this type of gage consists merely of passing the wire over a wheel or pulley and having a counterweight on the end. Reading may then be taken from the motion of a pointer attached to the wire along a fixed vertical scale beside it. A very crude form of such a gage has often been seen on railroad water tanks.

A more usual arrangement in water works practice is to attach the end of the float wire to a drum, around which it is then wound a number of turns. The counterweight is then hung from another wire similarly attached to the drum. By such design slipping of the wire is avoided and the revolution of the drum is a true measure of the change in water level. The drum is then connected to a rotating pointer on a dial or to a recording device. By introducing suitable gearing a wide range of float motion may be shown as only a part of a revolution of the pointer on the dial, or other variations may be introduced changing the scale of readings to suit the conditions and the requirements.

The drum upon which the wire is wound should be provided with spiral grooves to receive the wire so that it will be guided in a single layer and will not wind upon itself, thereby changing the effective diameter of the drum and affecting the accuracy of the gage. If desired, the drum receiving the counterweight wire may be smaller than the drum for the float wire, thereby resulting in a shorter travel for the counterweight where this is of any advantage. The counterweight should not become submerged, since its effective weight would thereby be altered and the submersion of the float changed.

Gage With Tape

If a tape is used it is customary to provide it with uniformly spaced perforations which fall over similarly spaced projecting pins on the drum, thereby preventing slipping. A tape is, of course, not wound around the drum, but merely passes over it once, with the counterweight on the end. The counterweight must then travel through the same range of motion that the float does.

Indicators and Recorders

Many good designs of indicating and recording instruments are commercialy available for use with floats and which are adaptable to different conditions and requirements. Floats may also be utilized similarly to operate transmitters for long distance electrical transmission of gage readings, known as telemeters.

METERING OF WATER AND SEWAGE

By L. D. CARLYON, M.E.
Cleveland, Ohio

PART I—PRIMARY ELEMENTS

In modern sewage plants and water works, metering equipment is now recognized for the important part it plays in obtaining efficient control and operation.

Regardless of type, large meters and registering devices depend upon the so-called "Venturi" principle for their operation. This consists of producing a differential pressure which varies in a definite and known relation to the rate of flow. The differential pressure is mechanically converted into terms of weight or volume and is so indicated and recorded by registering equipment. The actual registers themselves are constructed to provide various combinations of indicating, recording, and totalizing features.

There are three commonly used devices, which can be inserted in fluid lines to produce the desired differential pressure. These are the Venturi tube, the flow nozzle, and the thin plate orifice. Each provides a reduction of the area through which the flow takes place, thereby causing an increase in velocity at this point with a corresponding localized reduction in pressure. The result is a differential in pressure between two areas of the Venturi tube, or on either side of the flow nozzle or orifice inserted in the pipe. Figure 4 illustrates the head differentials created by an orifice insert.

For a given installation the primary element is designed and constructed so that when the maximum rate of flow occurs, a definite maximum head differential will be produced. This varies from a water differential of less than 10 inches to one of more than 200 inches, dependent upon the fluid to be measured, the static pressure, the maximum capacity and the type of register.

Although any one of the three primary elements (Venturi, flow nozzle, or plate orifice) can normally be used, there will usually be one of the three which is best suited to meet the existing requirements. The selection is determined by a number of factors. These factors are to be dealt with in this article, with a view of better acquainting engineers, superintendents or operators with the more important considerations in selection of metering devices. It is hoped that some of the confusion concerning these devices which exists in the minds of some will be cleared away by the following discussion.

Fundamental Comparisons

The Venturi Tube

The Venturi tube has been used for years in connection with projects of the hydraulic and sanitary engineer. As illustrated in Fig. 1, it is designed with a short cylindrical section at the inlet end of the tube, which is cast smooth inside. The high pressure connection is made at this point into the piezometer ring (Fig. 1, Section AA).

*Mechanical Engineer, Bailey Meter Co.

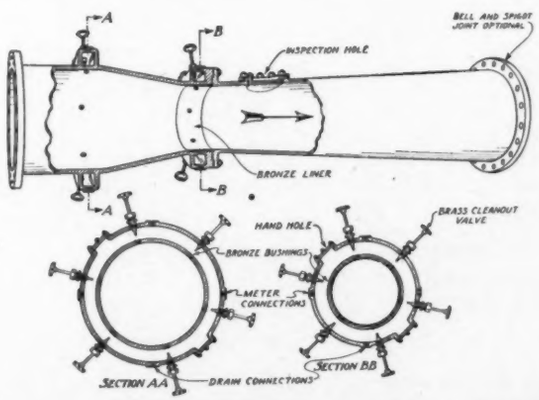


Fig. 1—Venturi Tube. (Handholes and Cleanout Valves Are Used Only for Measurement of Screened Sewage or Sewage Sludges)

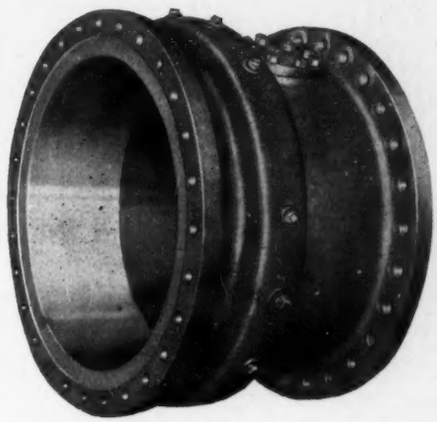


Fig. 2—Venturi Throat Section for a 56-Inch Line, Constructed of Cast Iron with a Machined Bronze Liner

Following the inlet section is an entrance cone of about 21 degrees total angle, which leads to the short cylindrical throat section where the low pressure connection to the meter is made through another piezometer ring. At the throat the tube is flanged, and has a handhole which permits inspection of the throat and piezometer holes, as well as accurate measurement of the throat diameter. An exit cone, known as the diffuser, follows the throat and has a total angle of approximately 5 degrees. This ends in a flange for connecting the tube to the pipe line flange.

In certain cases due to objection to the laying length of the long Venturi tube or possibly for reasons of cost, a tube referred to as a "short Venturi" is used. It differs from the long tube primarily in that the angle of the exit cone is much greater (normally 13 to 15 degrees total angle), thus making the overall length much less than a long tube of corresponding diameter which is justified on the grounds that a smaller head loss is created.

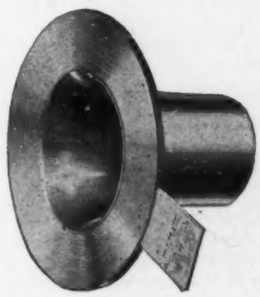


Fig. 3—Flow Nozzle

The majority of Venturi tubes are fabricated of cast iron and are provided with brass or bronze liners in the throat which are machined smooth within close tolerances. Small tubes of from 1 to 2 inches diameter are often made of brass or bronze throughout and the entire length of the internal surface may be completely machined all over. Very large ones have been constructed of concrete or steel plate with a cast iron throat section having a machined bronze liner, such as shown in Fig. 2.

Flow Nozzle

In many respects the flow nozzle (Fig. 3) may be considered to be a simplified Venturi tube. The entrance consists of a gradual curve of approximately one-quarter ellipse which leads the fluid smoothly into a short cylindrical throat section. Thus the discharge jet will have no contraction and will be the same diameter as the throat itself.

Installation of the flow nozzle is made by inserting it between a pair of pipe flanges. The high pressure upstream connection is usually made by tapping the pipe line approximately 1 pipe diameter back of these flanges, and the low pressure connection is made on the line at a point just opposite the throat section of the nozzle. For the measurement of water, air, sewage or

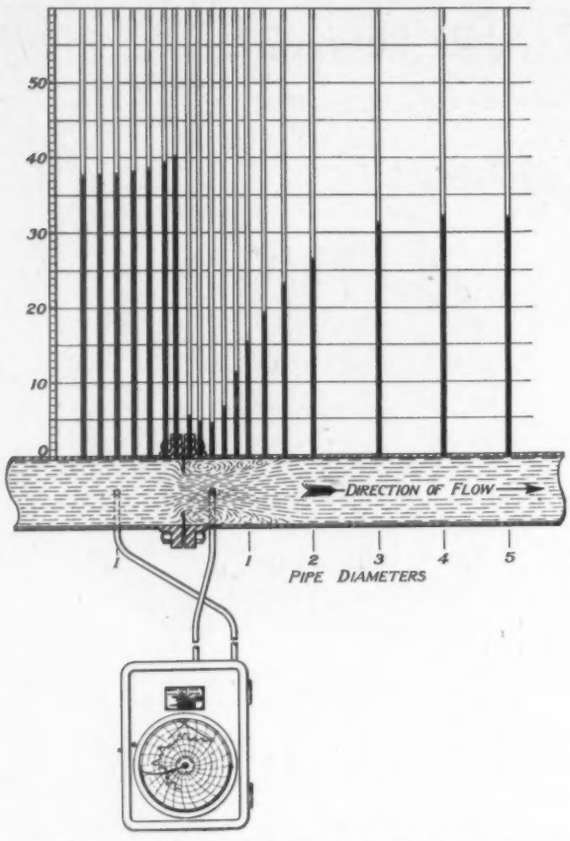


Fig. 4—Diagram of "Stream Lines" in a Fluid Flowing Through a Circular Concentric Orifice in a Pipe, Pressures Existing at Various Distances from the Orifice

sludge, flow nozzles are usually fabricated of bronze, the inside being very accurately machined.

Thin Plate Orifice

The thin plate, or sharp edged orifice, shown in Fig. 4 has been widely used for many years to measure the flow of fluids. In its simplest and most familiar form, the orifice is merely a hole in a flat plate which is clamped between flanges in the pipe line. It may be of 1/16 inch thickness or more, depending upon its diameter, and can be made of nickel, monel metal, steel or other suitable material. Flow meter literature abounds with results of thousands of experiments proving conclusively that the orifice operates on the same basic principles as does the Venturi tube and flow nozzle.

Referring to Fig. 4 it will be noted that there is a well-defined Vena Contracta (plane of greatest contraction) on the down-stream side of the orifice plate, just as is observed when the stream from a sharp edged orifice discharges into the open air. The pressure on the outlet side of the orifice varies along the length of the pipe with the velosity of the stream itself, the observed pressure being least (differential the greatest) when the connection is exactly opposite the Vena Contracta.

The location of the Vena Contracta remains constant regardless of the rate of flow for any one installation. It assumes a slightly different position, however, with different ratios of orifice diameter to inside pipe diameter. For a given ration, its relative position is independent of pipe size. The high pressure upstream tap is made at approximately one pipe diameter back of the orifice, and the low pressure tap is made exactly opposite the Vena Contracta. Some manufacturers recommend that the taps be close to and on either side of the orifice plate; in this case it is necessary to obtain the orifice plate and the flanges as an integral assembly.

Factors to Consider

Before a metering element is specified or selected for a given project, six factors must be taken into consideration if the most suitable arrangement is to be secured; namely (1) initial cost, (2) installation, (3) accuracy, (4) reliability, (5) pressure loss, (6) capacity change.

The above factors may not appear in their order of importance, for the item which is of primary importance for any one application will vary with conditions peculiar to that application.

1. Initial Cost

The initial cost (purchase price) of the primary element may vary within wide limits. Figure 5 illustrates the approximate relationship between present-day prices of long Venturi tubes, short tubes, bronze flow nozzles, and thin plate orifices. It will be noted that for a given size, the price decreases in the order named. Without question the orifice has a decided advantage with respect to initial cost, being approximately one-ninth that of a long Venturi tube of corresponding size.

In the larger sizes, say above 24 inches, it is also possible to obtain orifices at prices from 20 to 25 per cent lower than those shown, by specifying a steel orifice plate having a nickel insert. This insert has the orifice hole machined in it and thus the more expensive metal is used only where it is essential.

Very large Venturi tubes become cumbersome and expensive. On this account large tubes are frequently constructed of steel plate or concrete at its location and only the throat section is purchased from the meter manufacturer.

2. Installation

From the standpoint of ease of installation, the orifice or flow nozzle would be selected in preference to a Venturi tube. They need merely be inserted between a pair of flanges in the pipe line, but considerable care must be taken to center the element properly, to make the pressure connections at the correct locations, and to see that there are no protrusions left on the inside of the pipe line as the result of making the taps.

The Venturi tube being relatively larger and much heavier, more time and labor is required in the installation. If the pipe line is an existing one, it will be necessary to remove one or more sections of pipe and to provide filler pieces of the correct length so that the tube can be made a part of the line. On a new project, however, in comparing the cost of installing a Venturi tube a credit representing the cost of a section of straight pipe of the same length, which otherwise would be required if a flow nozzle or orifice were used, should be considered.

Since the pressure taps are an integral part of the tube, these can be assumed to be correctly placed.

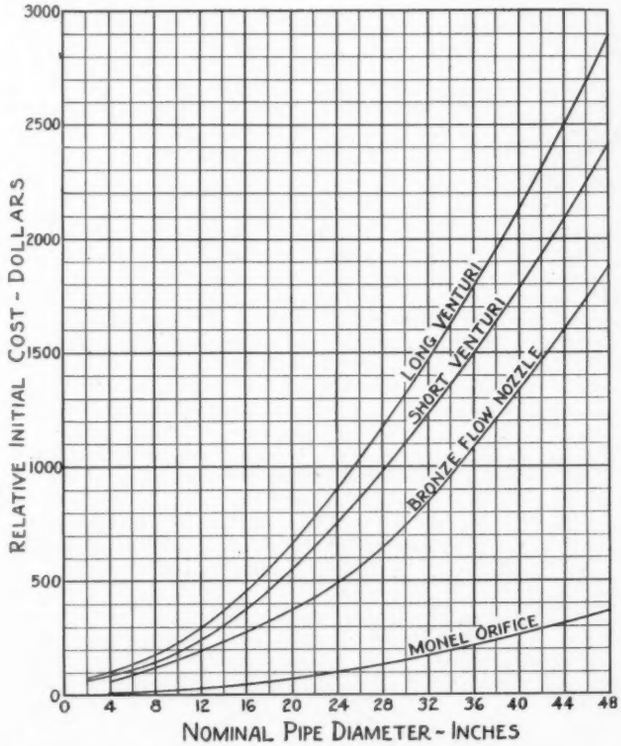


Fig. 5—Curves Showing the Approximate Purchase Prices (at Factory) of Various Types of Primary Elements. (The Curves for the Venturi Tubes Are Based on Weights Suitable for Use with Class A, B, and C Cast-Iron Pipe, and Do Not Include Handholes or Cleanout Valves Shown in Fig. 1)

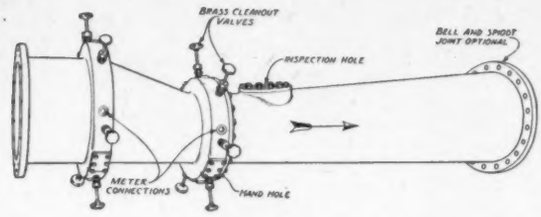


Fig. 6—Eccentric Type Venturi Tube for Sewage or Sewage Sludges

3. Accuracy

When installed under suitable conditions, the three primary elements are very nearly equal when compared on the basis of accuracy obtainable; namely, within 1 per cent of 100—plus or minus. Due to small inaccuracies introduced by the register mechanism, however, manufacturers normally extend a conservative guarantee that the reading will be within 2 per cent of 100 plus or minus. In actual practice the accuracy always falls well within the limits of the guarantee.

In order to insure accurate metering, all primary elements require a certain length of straight pipe preceding the location. For the Venturi tube, 5 to 10 pipe diameters are usually adequate. For the flow nozzle or orifice types this requirement is between 8 and 20 pipe diameters, depending on the ratio of orifice diameter to inside pipe diameter, and on the piping layout. Sometimes these requirements cannot be met due to the piping layout. It is under such conditions that the short Venturi tube occasionally proves most suitable because it is from 30 to 45 per cent shorter than the long tube of like diameter.

In order to preclude high readings on the registering device, the primary element should not be installed where the air or liquid flow is of a rapidly pulsating nature. Such a condition may be caused by water or sewage reciprocating pumps and by certain types of air blowers. It is sometimes possible to eliminate pulsations or dampen them materially but where pulsating flow is likely to be a problem this factor should be called to the meter manufacturers' attention; whereupon, specific recommendations will be made.

4. Reliability

It is essential that the primary element retain its accuracy after installation and that it also provide continuity of satisfactory service.

Screened sewages and sewage sludges present the greatest problem of measurement because of solid matter or gas which they contain. For this service the piezometer rings of the Venturi tube are equipped with cleanout valves (Fig. 1) which facilitate routine cleaning operations to maintain the openings free from obstructions. Connections should be made at top and bottom of each ring for venting accumulating gas or draining sediment. Handholes in each ring make the interior accessible.

At low velocities the throat section of the Venturi tube may act as a dam causing foreign material to settle on the bottom of the inlet cone and, thereby, affecting the accuracy. A condition of this kind can be largely avoided by the use of an eccentric Venturi tube (Fig. 6) which differs from the ordinary tube only in the eccentric shape of the converging and the exit cones. The fact that the bottom of the tube lies in one horizontal plane makes it easier for solid materials to be swept through the tube.

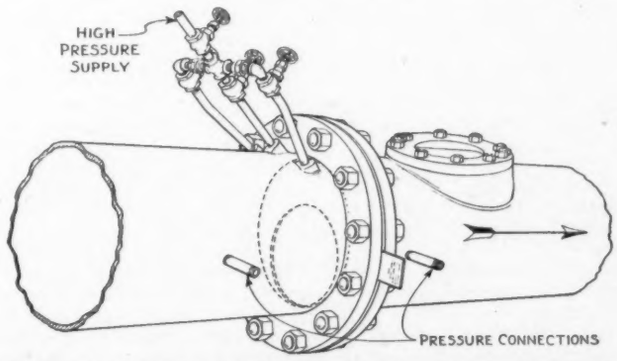


Fig. 7—Eccentric Type Orifice Installed in a Sewage Main, Illustrating an Arrangement for Washing Collected Materials Off the Face of the Orifice Plate

An installation of an orifice in a sewage line is illustrated in Fig. 7. Here also the eccentric type is of particular advantage in that solid materials pass through without obstruction. While there is even less chance of materials settling on the sharp edged opening than in the throat of a Venturi tube, there is a greater possibility of material collecting on the entrance side of the plate. For this reason it is desirable to provide a high pressure water supply into the pipe line (Fig. 7), for periodically washing off the face of the plate.

A common method for the prevention of plugged taps, and keep the meter connections clean and free of deposits is to introduce a continuous trickle of clean water through the connecting pressure lines to create a slow current into the main pipe line.

Unless there is some especial factor involved, the flow nozzle should be avoided in metering sewage, because there is a tendency for materials to deposit in the throat section and to build up at the entrance. However, it has proved satisfactory where a

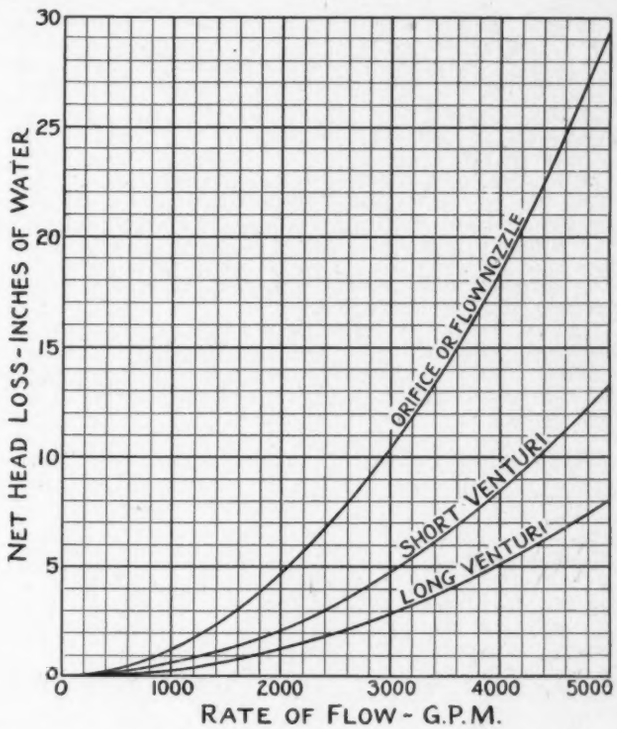


Fig. 8—Curves Showing the Net Differential Head Loss Created by Different Types of Primary Elements, Designed for a Maximum Differential of 53 Inches of Water, at a Maximum Capacity of 5,000 g.p.m., as Applied to a 20-Inch Water Main

means has been provided for flushing out the entrance and throat frequently.

Measurement of unscreened sewage should be avoided, except where there is no alternative, as for example when one community has its sewage treated in the plant of another municipality. The large heavy solids may cause greater wear and erosion on the primary element, and in the case of an orifice installation, there is the added danger of an object striking the plate with sufficient force to cause distortion.

Comparatively little attention is required for primary elements in air lines or fresh water mains, and all three elements will function indefinitely with practically no attention.

5. Pressure Loss

The differential head created by any of the three primary elements represents only a localized drop in pressure, most of which is restored upon resumption of normal flow a short distance following the primary element as is pictured in Fig. 4. It is important to hold head losses to a minimum, especially when capacities are large and available head is at a premium, or where pumping is involved and power requirements must be considered.

With the long Venturi tube, the pressure loss at any rate of flow is only approximately 15 per cent of the actual differential head produced by the element at that rate of flow, whereas with the short tube the loss is approximately 25 per cent.

The percentage loss created by orifices or flow nozzles depends

upon the ratio of the throat diameter to the internal pipe diameter—the smaller the throat or orifice the greater the percentage loss. When designed for identical conditions of capacity, etc., the percentage loss will be virtually the same for both the orifice and the flow nozzle.

As a typical example, assume that a water meter operating on a maximum differential head of 53 inches of water is to be applied to a 20-inch main and to have a maximum capacity of 5,000 g.p.m. The loss of head created at maximum flow by the various elements as shown by the curve in Fig. 8 would be:

Long Venturi, 7.95 in. water (.15 × 53).

Short Venturi, 13.25 in. water (.25 × 53).

Orifice or Flow Nozzle, 29.15 in. water (.55 × 53).

With a flow of 2,500 gallons per minute (½ of maximum) the losses produced would be only ¼ of these values, because the differential head varies proportionately to the square of the rate of flow.

Although the curves of Fig. 8 apply only to the specific example, it can readily be seen that conditions exist where, by use of a Venturi tube, the reduced cost of pumping over a short period of time will more than offset the higher initial cost of the Venturi tube.

5. Capacity Change

An existing meter installation may at some time require an increase in maximum capacity to meet the requirements of increasing quantities of fluid handled by the system. This may be accomplished in three ways—either by providing a new primary element, by modifying the old one to handle the larger capacity, or by increasing to the required extent the maximum differential head with which the register functions.

With the Venturi tube, the first two methods are costly, particularly in the larger size and therefore the register differential is usually increased. It should be borne in mind, however, that with this method, at rates of flow exceeding the original maximum capacity the pressure loss increases as the square of the flow.

When an orifice or flow nozzle constitutes the primary element, a new one can usually be installed at reasonable cost. Since such a change necessitates a larger orifice the pressure loss will be lower than for the original installation, notwithstanding the increased flows handled. This naturally cannot be accomplished in cases where the primary element originally installed is already near the greatest ratio for which it can be designed. It is necessary then to increase the differential head of the register and suffer the head loss entailed or else to provide a duplicate installation on a parallel twin line.

Knowledge of the principles described and intelligent consideration of the six factors outlined above will aid materially in obtaining primary elements which are most suitable for the particular project from the standpoint of both satisfactory operation and cost.

Final decisions can be made only when complete details and figures are available pertinent to the specific problems under consideration. Therefore, it is important to supply meter manufacturers with as complete data as possible concerning each contemplated meter installation, such as the type of fluid, maximum capacity, pipe diameter, pressure, and a dimensioned sketch of the piping layout.

PART II—SECONDARY ELEMENTS

The secondary element of large meters (more commonly known as a register) is actuated by the differential pressure and, through mechanical or electrical means, converts such into records or indications of the rate of flow. In addition a totalization of the weight or volume passing through the line is registered.

Although there are many types and makes of registers, they depend upon only a few basically different types of mechanisms designed to utilize the differential head. These form the basis for much of the following discussion concerning secondary elements as applied to various services.

Because of the extensive use of the Venturi tube as a primary element, it is desirable to have the register designed so that its capacity can be changed by increasing the maximum differential head upon which it functions without altering the primary element or connecting lines, thereby eliminating expensive replacement of tubes.

Registers may be divided into two general classes of differential translating mechanisms; (1) the open float tube type, and (2) the pressure chamber type.

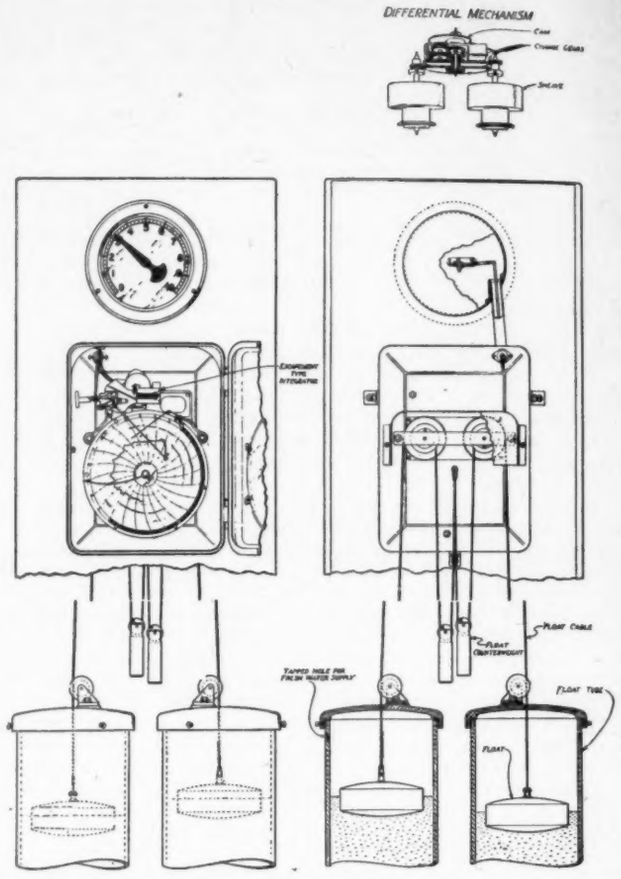


Fig. 1.—An example of the open float tube register for the measurement of sewage, sludge, and dirty water. (Courtesy of Bailey Meter Co.)

The Open Float Tube Register

The open float tube register is used only where the hydraulic gradient is relatively low and where changes in it are not severe. It is most extrensively used in metering sewages and sludge.

One example of the open float operated register is shown in Fig. 1 and a diagrammatic installation of this register, Fig 2, illustrates its position relative to the float tubes, and the Venturi tube.

One float tube is connected to the inlet and the other to the throat of the Venturi tube by pressure piping so that the water level in each tube will rise to a height corresponding to the pressure existing in the Venturi tube at the point where the connection is made.

The rate of flow, represented by the difference in levels of the floats in the float tubes, is transmitted to the register by cables which are attached to sheaves as shown in Fig. 1. These cables operate the differential mechanism and square root cam which in turn transmit the rate of flow to the recording pen, the integrator and the indicator. A square root cam is employed to translate the differential into terms of flow so that the pen motion will be directly proportional to the rate of flow.

Another function of the differential gearing system is to automatically compensate for variations in line pressure or hydraulic gradient. This mechanism is designed so that if both floats rise or fall an equal amount there will be no change in the position of the operating cam. However, if there is a change in the difference between the levels in the float tubes, this change immediately operates the square root cam which in turn moves the recording pen to a new position, thereby registering the variation in rate of flow.

The maximum capacity of this float operated register can be altered by simply changing two sets of gears in the differential mechanism. This feature is provided to eliminate excessive costs for the replacement of the Venturi tube with modern equipment; wide variations in capacity can be obtained without removing the primary element from the line or disconnecting the meter in any way.

The register itself is mounted on the operating floor immediately

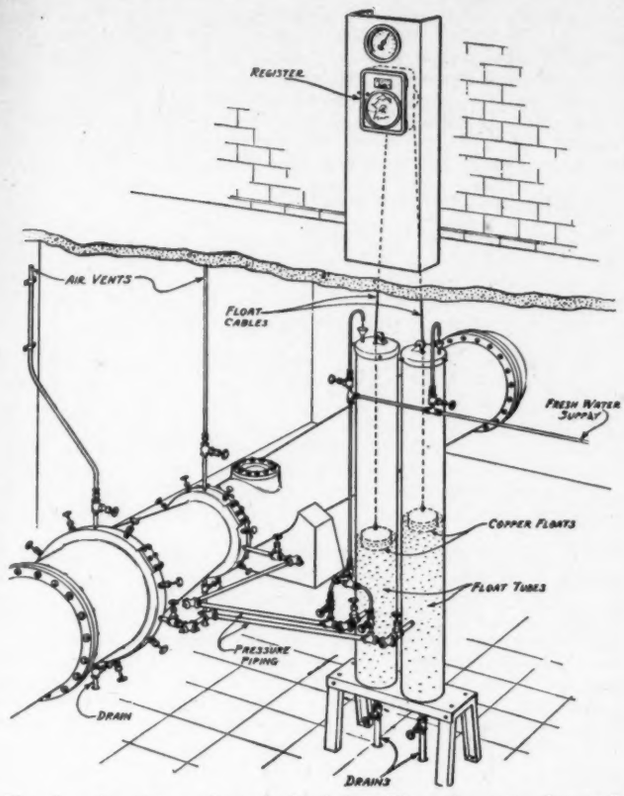


Fig. 2.—An approved method of installing the open float tube register for the measurement of sewage or sludge. (Courtesy of Bailey Meter Co.)

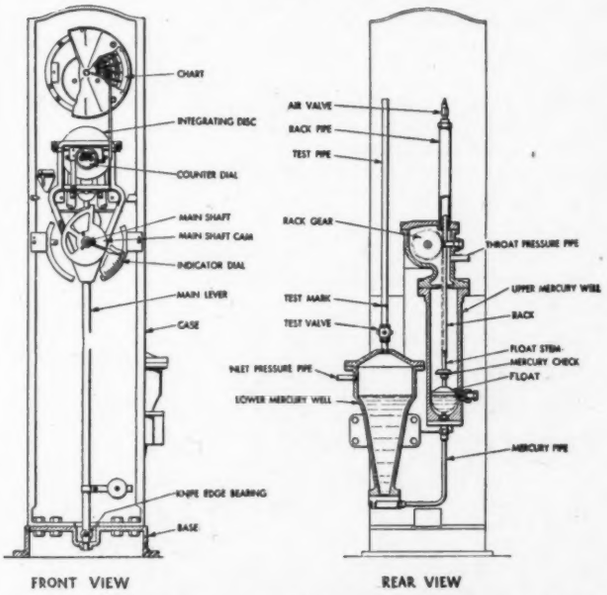


Fig. 4.—One example of the pressure chamber type of register using a float. (Courtesy of Builders Iron Foundry.)

above the float tubes. Cables are strung from the sheaves to the copper floats in the float tubes. This cable system is counterweighted as shown in Figure 1 so that there is an even tension on the float cables at all times. The float tube covers are provided with small pulleys to guide the copper floats in the center of the tubes without undue friction in the mechanism.

A satisfactory method of installing the float operated register is represented by Fig. 2. The float tubes are usually made of 10-inch cast iron pipe and should be located directly below the register and as close to the Venturi tube as conditions will permit. A constant supply of fresh water is slowly introduced into the float tubes so that the water flows from the tubes out through

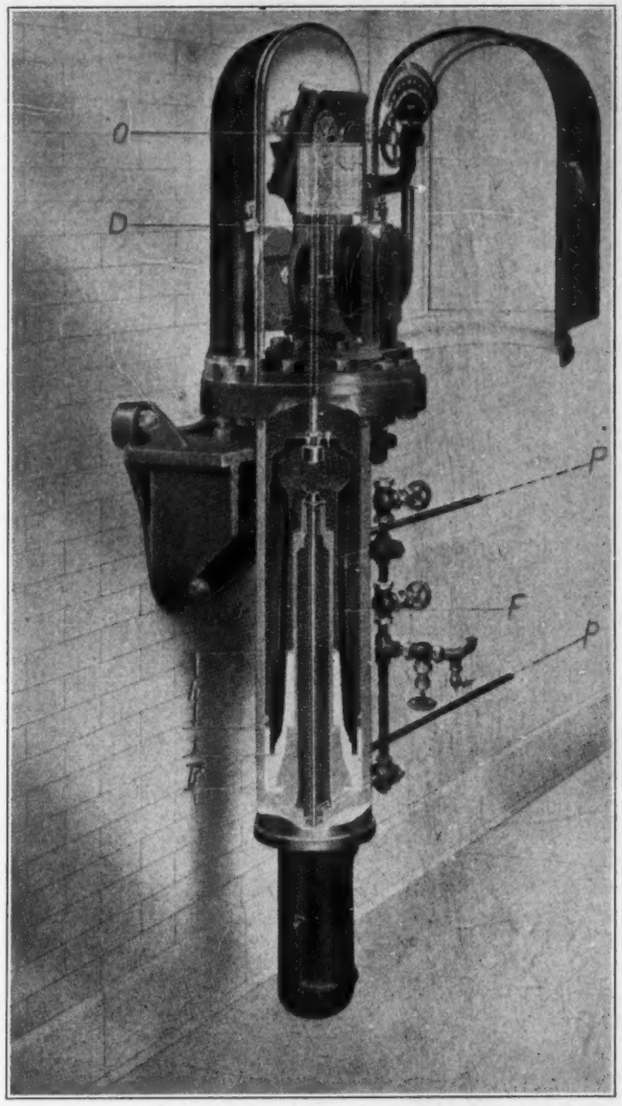


Fig. 3.—An example of the pressure chamber type of register using a mercury sealed bell. (Courtesy of Simplex Valve and Meter Co.)

the pressure piping to the Venturi tube thereby minimizing the accumulation of solid matter in the system. Provision is also made for flushing out the pressure piping with clean water under pressure, and also for cleaning the inside surface with a brush or "ram" should such be necessary. The float tubes are fitted with shut-off valves and drain connections.

The piping connecting the Venturi tube with the float tubes is sloped (grade of ½-inch or more per foot) to prevent air or gas from becoming trapped in the piping and causing false levels to exist in the float tubes. The piping should be of 1-inch or larger copper or red brass pipe joined together with crosses at all changes of direction so that it may be rammed or brushed clean by removing the pipe plugs from each end of the run to be cleaned. Gate valves should be used on these lines instead of globe valves because they open to provide a free and unrestricted passage through the pressure piping, which is necessary to facilitate cleaning.

The fresh water supply piping may be readily constructed of copper tubing and compression fittings. Copper tubing of ½ inch diameter usually furnishes sufficient fresh water for the sight feeds.

Vents, leading to a point above the maximum hydraulic gradient, should be provided at the inlet and throat rings of the Venturi tube as shown in Fig. 2. To insure continuous venting, these vents should be left open at all times except when flushing the piezometer rings.

The "standard" arrangement of register and float tubes (Fig.

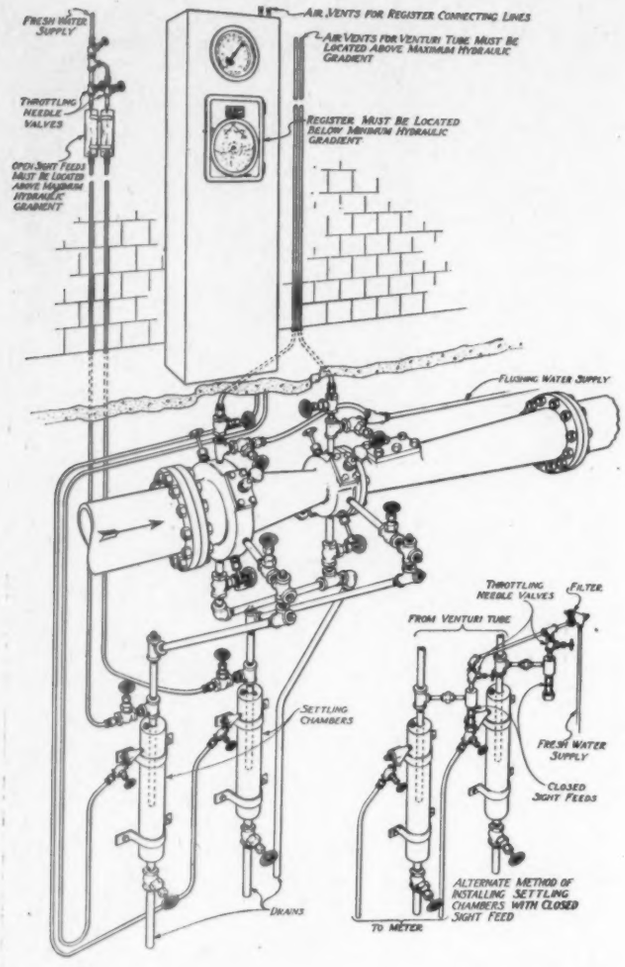

AIR VENTS FOR REGISTER CONNECTING LINES
AIR VENTS FOR VENTURI TUBE MUST BE LOCATED ABOVE MAXIMUM HYDRAULIC GRADIENT
FRESH WATER SUPPLY
THROTTLING NEEDLE VALVES
REGISTER MUST BE LOCATED BELOW MINIMUM HYDRAULIC GRADIENT
OPEN SIGHT FEEDS MUST BE LOCATED ABOVE MAXIMUM HYDRAULIC GRADIENT
FLUSHING WATER SUPPLY
THROTTLING NEEDLE VALVES
FILTER
FROM VENTURI TUBE
SETTLING CHAMBERS
FRESH WATER SUPPLY
CLOSED SIGHT FEEDS
ALTERNATE METHOD OF INSTALLING SETTLING CHAMBERS WITH CLOSED SIGHT FEED
DRAINS
TO METER

Fig. 5.—A recommended method of installing the pressure chamber register, whether bell or float type, for the measurement of sewage or sludge. (Courtesy of Bailey Meter Co.)

2) is not satisfactory in cases where the maximum hydraulic gradient rises above the register location. For installation under such conditions, the register may be mounted at an elevation *below* the float tubes and motion of the floats can be transferred to it by running the cables over a suitable arrangement of pulleys. Conditions of this kind can also be satisfactorily handled by the pressure chamber type of register and the sight feed system described in the following section.

Pressure Chamber Register

Where line pressures are high, or when wide changes in the hydraulic gradient are to be encountered, the pressure chamber operated register should be used. With this type of meter, the pressure piping from the primary element is connected directly to the flow mechanism of the register which contains either a bell or a float.

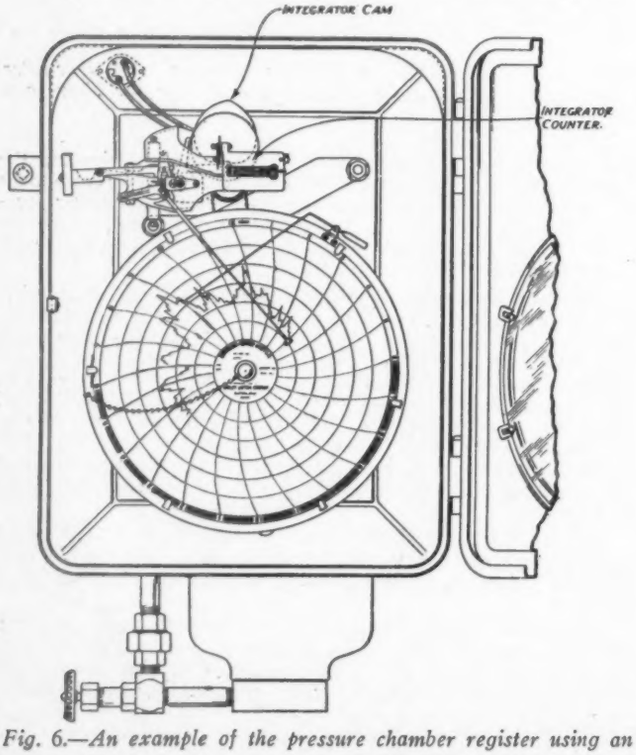
One example of a pressure chamber register using a bell is shown in Fig. 3. The actuating mechanism, a hollow float of bell shape which is sealed in mercury, is subjected on the outside to the higher pressure from the approach side of the primary element and on the inside to the lower pressure. The float is shaped so that the resultant downward movement, from its position at zero differential head to the position of equilibrium, is directly proportional to the instantaneous rate of flow through the primary element.

Movement of the float is transmitted to a sheave, usually by a flexible cable provided with a counterweight and sheave clamp. The sheave is fixed to a shaft carried on pivot bearings. After passing through the stuffing box, the shaft further supports the flow pointer, the recording pen, and the integrating mechanism.

An example of the float type of pressure chamber register is illustrated in Fig. 4. The pressure connections from the primary element are connected to the two sides of a mercury U-tube, the higher pressure being connected to the tapered well, and the lower pressure to the well containing the float. As the rate of flow varies through the primary element, the mercury level in the U-tube will also vary, thus raising or lowering the float. This motion, through the rack and gear, provides the motive power for operating the indicating, recording, and integrating mechanisms.

The specially tapered well of the U-tube partially extracts the square root of the differential, and the remainder of the function is converted by a shaped cam in the register so designed that actual motion of the recording pen and indicator becomes directly proportional to the rate of flow.

One method of installing the pressure chamber type of register in accordance with good engineering practice is represented by Fig. 5. Foreign matter is prevented from entering the register flow mechanism and connecting piping by the open sight feeds and the settling chambers. The sight feeds cause fresh water to



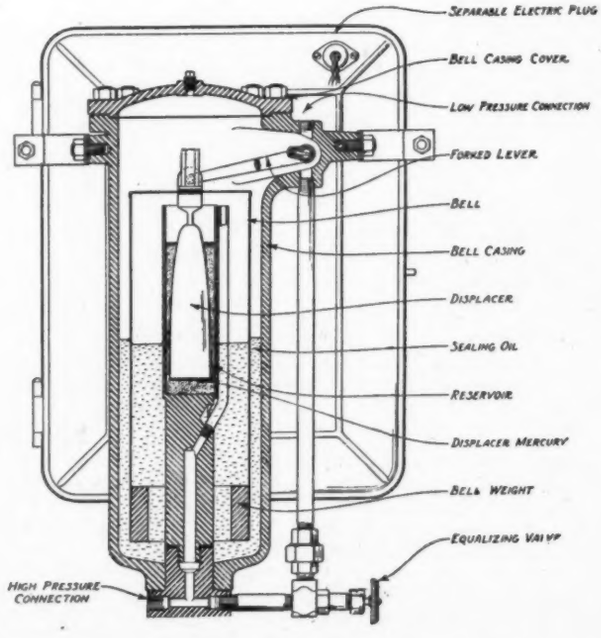


Fig. 6.—An example of the pressure chamber register using an oil sealed bell for measuring air. (Courtesy of Bailey Meter Co.)

flow from the settling chambers back through the pressure piping to the piezometer rings of the Venturi tube. This flow opposes the tendency of solid matter to work into the piezometer rings and pressure piping. The settling chambers, installed between the pressure piping and the copper tubing connecting lines to the register, collect and permit disposal of any solid matter which may work into the piping.

The pressure piping is of 1-inch or larger brass or copper. To facilitate cleaning, crosses are used for fittings, as shown in the illustration. From the settling chambers to the register, ½-inch copper tubing and fittings are suitable.

Open sight feeds are recommended in order to eliminate the possibility of water contamination by a direct cross-connection between the fresh water supply and the sewage system. If preferred, or if the maximum hydraulic gradient is too high to permit the convenient use of open sight feeds, closed sight feeds (see Fig. 5) can be used provided that the water supply to which they are connected is wholly independent of the city water. In some cases, an intermittent type of flushing system is used which utilizes city water. This however, requires the attention of an operator to establish and maintain the cross-connection and disconnect it when manual attention ceases. A flushing connection to the inlet and throat rings of the Venturi tube is also recommended.

When it is necessary to measure the flow through a line in which the hydraulic gradient varies over a wide range, and at the same time to locate the register above the minimum hydraulic gradient, the flow mechanism may be detached from the register and mounted at a lower elevation than the registering instruments. In this case, the movement of the flow mechanism is transmitted to the indicating, recording, and integrating devices by means of flexible cables.

Air Meters

For the measurement of air for aeration in the activated sludge type of sewage treatment plant, or mixing and partial aeration in chemical treatment, the translating mechanism of the register must of necessity function with a small differential head inasmuch as the static pressure of the air itself is low. Under these conditions the pressure chamber type of register is applied, but the sealing fluid usually is oil instead of mercury.

One type of meter used with air is represented in Fig. 6. The differential pressure is applied across the oil sealed bell to which is attached a specially shaped displacer which changes its immersion in mercury as the bell rises and falls with changes in differential pressures. The large size of the oil sealed bell permits operation on very low differentials, yet retaining ample power for the operation of the registering devices. The shaped displacer becomes directly proportional to the rate of flow.

Installation of air meters is a relatively simple task since ½-inch copper tubing with compression fittings, or brass pipe and fittings, may be connected from the primary element directly to the pressure chamber of the register. Settling chambers are not necessary.

Water Meters

For the measurement of clear water the pressure chamber register as described for sewage measurement is recommended. These meters are in service in the water works field on discharge lines from centrifugal pumps, on gravity mains, on branch lines in distribution systems, and in filtration plants to measure raw water, clear water, and wash water and rates of filtration.

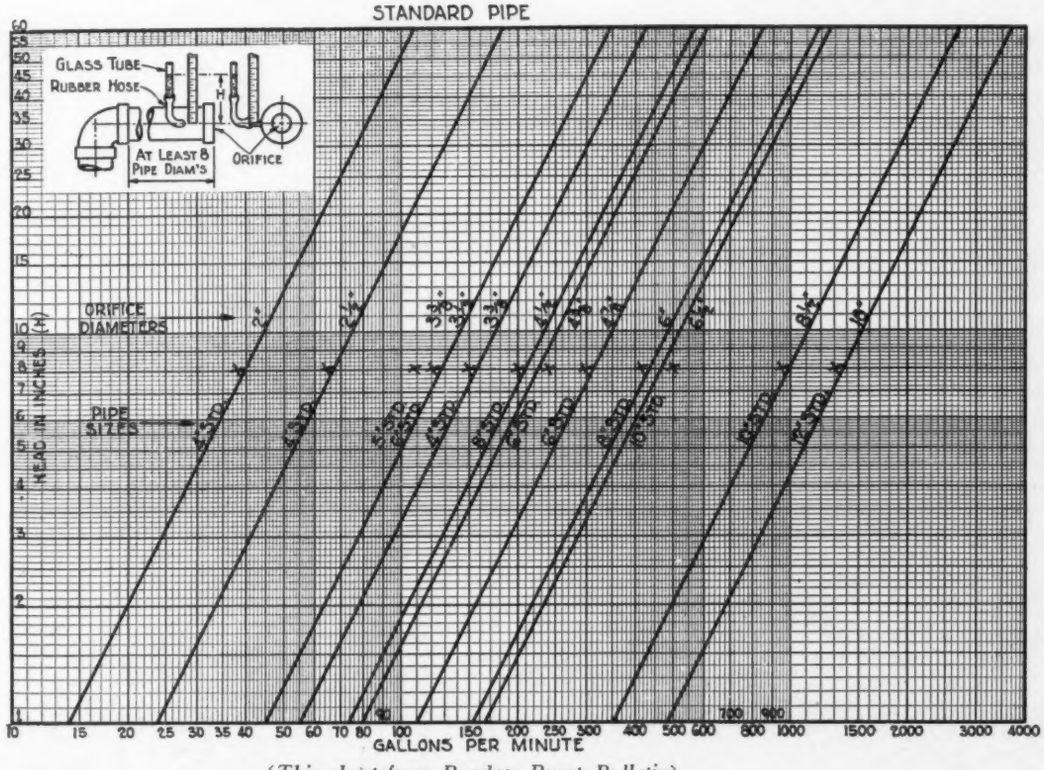
The installation of the register when applied to clean water is as simple as that of an air meter. Direct connections from primary element to pressure chamber may be made with ½-inch copper tubing or brass pipe. Settling chambers are not usually necessary, nor are the sight feed supply systems.

Register Instruments

The register instruments contain relatively simple mechanical or electrical devices which react in accordance with the movements of the flow mechanism to provide indications, chart records, and an integration.

It is advantageous if these instruments are designed so that additional equipment can be easily installed in them at any time for commanding the operation of auxiliary registers, signal devices, and controllers. This feature simplifies expansion of the services rendered by the main register such as operation of remote registers, totalization of flow through two or more influent lines to continuously indicate the capacity at which the plant is functioning. Likewise, for the automatic control by flow or the ratio of quantity of sludge returned to the aeration tanks.

FLOW MEASUREMENTS WITH THE CIRCULAR ORIFICE AT END OF PIPE



(This chart from Peerless Pump Bulletin)

Note: Also see tables in Part 3.

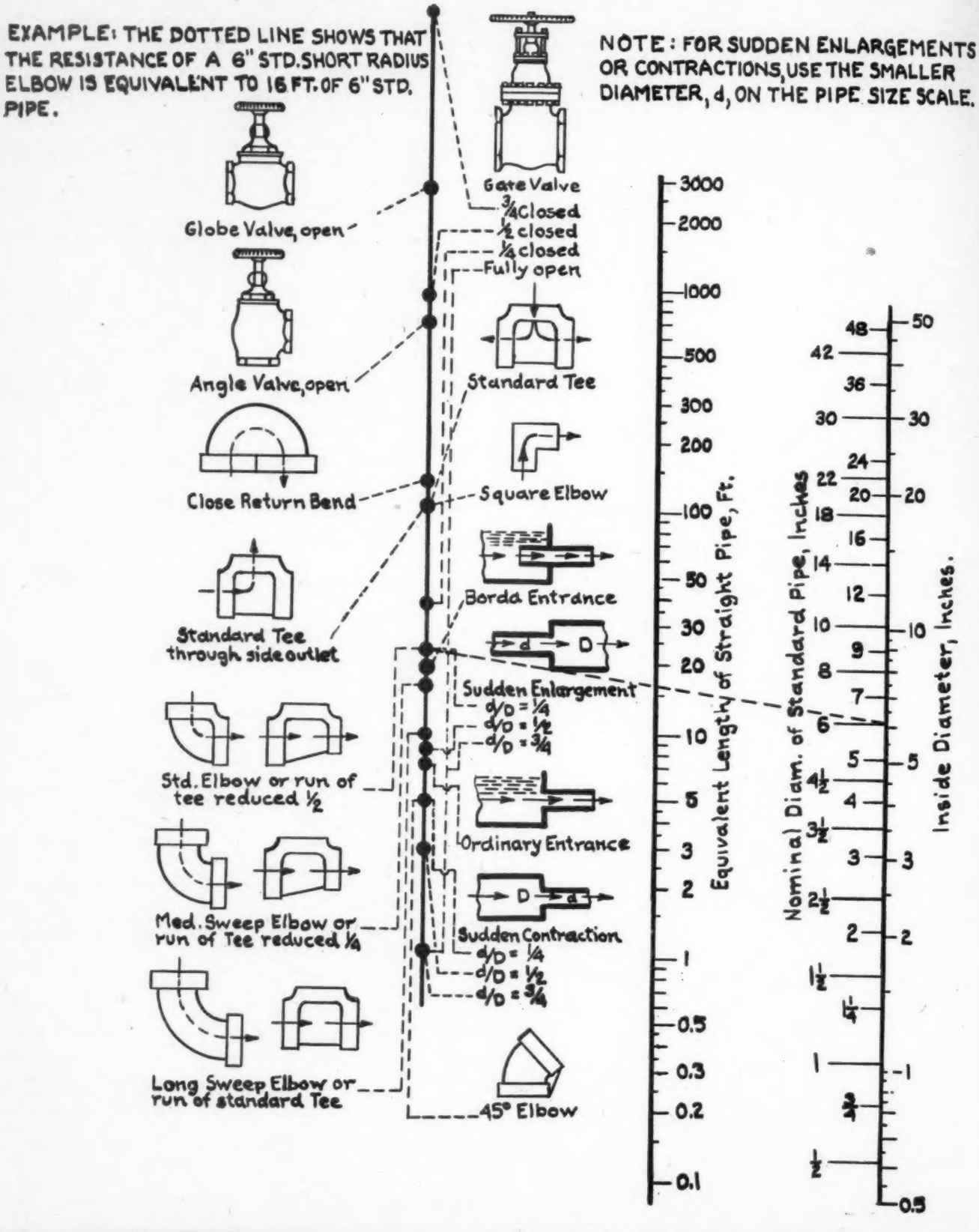
To obtain an accurate result in measuring the flow of water with a circular orifice the following conditions are to be maintained: Pipe must be horizontal with no elbows, obstructions or bends within 8 pipe diameters of discharge end; the orifice must be running full of water and "H" be at least one inch above top of the pipe.

Drill and tap discharge pipe on the side through center line for ⅛" pipe connection one foot back from orifice. It is very important that the ⅛" nipple does not extend inside the inner wall of the pipe and should be absolutely flush.

When the rubber hose connection and the glass tube are installed "H" may be measured from the center of the pipe with an ordinary rule.

RESISTANCE OF VALVES AND FITTINGS TO FLOW OF WATER*

When the flow of a fluid in a pipe line is altered by some obstruction such as a valve or fitting, the velocity is changed, turbulence is magnified and a drop in pressure results. This pressure drop may be insignificant in long lines where it is very small in comparison to the total drop, but when the line is short the pressure drop through valves and fittings becomes



a major item in the total pressure drop value.

The most widely used data on the subject of the resistance of valves and fittings to the flow of water and steam is the information given in Dean Foster's paper on "Effect of Fittings on Flow of Fluids Through Pipe Lines" published in Vol. 42, 1920, of the Transactions of the American Society of Mechanical Engineers. Recently, tests conducted by others have indicated that the values given by Foster are low for globe valves, angle valves, etc., and that data is needed to establish the correct information to use. It has been the tendency, and probably is the most practical way, to present the friction values in terms of an equivalent length of the same size of pipe; i.e., the pressure drop caused by a 2-inch elbow is equivalent to approximately the pressure drop caused by five or six feet of 2-inch pipe under the same conditions of flow.

Realizing the need for definite data covering this subject, Crane Co. has recently conducted pressure drop tests on valves and fittings on both water and steam. These tests were made on 2 inch and 6 inch sizes and conducted under conditions which were thoroughly investigated previous to the tests. The results of these tests are presented herewith together with a description of the method used in conducting them.

[*Note.*—Water and steam can be treated comparatively and a relation can be established between the relative friction values of water and steam. Foster has stated that the equivalent length of pipe for steam flow is about .8 of that established for the flow of water.]

Friction Losses of Water Line Valves and Fittings

The tests for determining the pressure drop of valves and fittings installed in a water line were made in the following manner:

A flow nozzle was installed in a 3 in. test line leading from the bottom of a 1,000 gallon water tank. A mercury manometer was set across this nozzle and the relation of mercury deflection to the gallons of water per minute flowing through the pipe was determined. The flow through the pipe was thereafter noted only in terms of mercury deflection which was readily transposed into gallons per minute by reference to the calibration chart.

The valve or fitting to be tested was placed in the line at some distance from the flow nozzle and the flow water through it was regulated by a throttling valve situated at the outlet of the line. The pressure drop was measured by means of a mercury manometer, or where the deflection was too great, by two sensitive low pressure gages, the leads of which were situated in the test line at a distance of ten pipe diameters (20 in.) from each end of the valve or fitting on test. The initial pressure at the inlet of the test line was kept constant at 80 pounds per square inch and the various rates of flow produced by throttling the outlet of the test line.

After the data was obtained the means of presenting it in its best form was investigated. In any pressure drop tabulation, the values for the fittings and valves in the line are added to the pressure drop of the entire length of line. Therefore, it seemed reasonable to disregard the pressure drop caused by the length of the valve or fitting and just list the pressure drop which was added to the line due to the presence of the article.

For instance, if a valve 4 in. face to face is installed in a line 30 in. long, the actual pressure drop through the valve will be the total pressure drop minus the pressure drop caused by 26 in. of pipe. However, in a practical problem this value will be added to the pressure drop caused by the total length of the line which will give a pressure drop value slightly higher than the actual. This may not be so noticeable with one or two valves or fittings in the line, but where the number runs up into 10 or 20 the added drop may be considerable.

This "No-length" concept was established and has been used before with reference to elbows in "The Friction of Water in Pipes and Fittings" by F. E. Giesecke, University of Texas Bulletin No. 1759.

Resistance in Terms of Equivalent Pipe Length

From data given in the tests conducted by Crane Co. and also from information gathered from authentic sources, Fig. 16, has been prepared which gives the equivalent length of pipe to produce the same pressure drop as a valve or fitting. This additional pipe length should be added to the length of the line in order to determine the total pressure drop.

*From Crane Co.'s "Engineering Data on Flow of Fluids in Pipes"—Technical Bulletin No. 405—1935. Parts dealing with steam pressure losses have been omitted.—Ed.

The equivalent length of pipe has been based upon the pressure drop values for the flow of water in pipes and upon the following coefficients of

$$H_1 = k\frac{V^2}{2g}$$

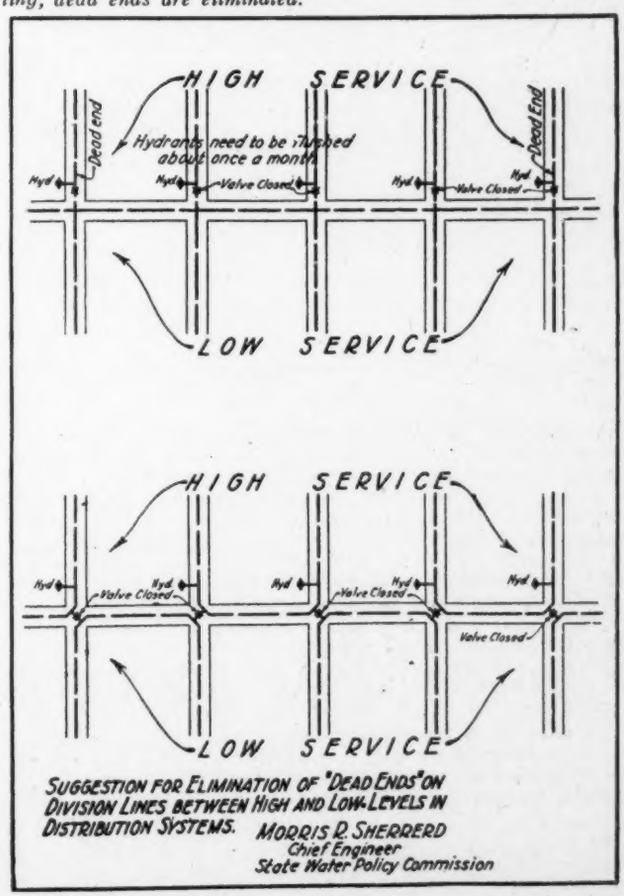
H_1 = Loss of head in ft.
k = Coefficient
V = Vel. in ft. per sec.
$2g = 64.4$

Type	*Coefficient*	*Authority*
Globe valves	10	Crane Tests
Angle Valve	5	Crane Tests
Return Bend	2.2	
Tee	1.8	Giesecke & Bladgett—Texas College
Short Radius Elbow	.9	Giesecke & Bladgett—Texas College
Med. Radius Elbow	.75	& Crane tests
Long Radius Elbow	.60	Bulletin No. 2712—U. of Texas.
Gate Valve (Open)	.19	Bulletin No. 252—U. of Wis. (Av.)
¼ Closed	1.15	Bulletin No. 252—U. of Wis. (Av.)
½ Closed	5.6	Bulletin No. 252—U. of Wis. (Av.)
¾ Closed	24.0	Bulletin No. 252—U. of Wis. (Av.)
Borda Entrance	.83	"Hydraulic" Daugherty (Average)
Sudden Enlargement		
d/D — ¼	.92	"Hydraulics" Daugherty
d/D — ½	.56	"Hydraulics" Daugherty
d/D — ¾	.19	"Hydraulics" Daugherty
Ordinary Entrance	.5	"Hydraulics" Daugherty
Sudden Contraction		
4/D = ¼	.42	"Hydraulics" Daugherty
d/D = ½	.33	"Hydraulics" Daugherty
d/D = ¾	.19	"Hydraulics" Daugherty
45° Elbow	.42	Bulletin No. 2712U. of Texas

ONE METHOD OF ELIMINATING DEAD ENDS

A means of eliminating dead ends of water mains where there are two types of water service, has been developed by Morris R. Sherrerd, Chief Engineer, New Jersey State Water Policy Commission.

The lower part of the illustration shows how by having a short gated connection between the two services, and by running the main around the block or square without using a cross fitting, dead ends are eliminated.



SUGGESTION FOR ELIMINATION OF "DEAD ENDS" ON DIVISION LINES BETWEEN HIGH AND LOW LEVELS IN DISTRIBUTION SYSTEMS. MORRIS R. SHERRERD Chief Engineer State Water Policy Commission

NOTES ON ELECTRICALLY DRIVEN CENTRIFUGAL PUMPS

By HOMER E. BECKWITH*

In the past few years there has been a rapid change from steam to electrically driven centrifugal pumps, especially in the smaller water works plants. The many advantages of electric power are coming to be more and more realized, but unfortunately in many cases a full knowledge of the nature of centrifugal pumps does not seem to have accompanied their adoption. It is economy of the highest order, therefore, to secure the advice of a competent engineer before purchasing any centrifugal pumping equipment.

Centrifugal pumps are designed to operate under fixed conditions, and any appreciable change from design conditions will result in decreased efficiency.

Installations have been found where pumps were working against more than the design head, or against less than the design head, or with the discharge or suction partly closed to control the rate of discharge. Or pumps have been installed without knowledge that the friction head is a part of the total head against which the pump operates. All of these factors adversely affect the performance of the equipment to such an extent that the cost of efficient machinery is often wasted every few months through inefficient operation. Also, accidents can occur to equipment in operation which decreases its efficiency.

For some time the writer has felt that some simple method should be available to the average water works operator whereby he could check up on his pumps. Table 1 was worked up for personal use, but may prove to be of interest. A slide rule was used in its preparation, but it should be accurate to a fraction of 1 per cent. With this table, it is believed that the work of securing overall wire to water efficiencies will be reduced to a minimum. Table 1 shows the number of gallons pumped per kilowatt hour against a given head, assuming the motor and pumps have efficiencies of 100 per cent. A rough check can be made by dividing a month's pumpage in gallons by the kilowatt hours consumed. This gives the number of gallons pumped per kilowatt hour. With the pump running, determine the average total head in feet (including suction) against which the pump works. From the table secure the number of gallons which would have been pumped at the head if the installation were 100 per cent efficient. Divide the number of gallons actually pumped per kilowatt hour by the theoretical value given in the table. This gives the overall wire to water efficiency of the installation. To illustrate:

Assume a monthly pumpage of 18,620,000 gals., a total head of 200 ft., and a power consumption of 20,000 kilowatt hours. Dividing 18,620,000 by 20,000 we get 931 gals. per kilowatt hour. For 100 per cent efficiency the tables indicate that the discharge would be 1,592 gals. against a head of 200 ft. Dividing the actual discharge per kilowatt hour by the theoretical value we have: $\frac{931}{1{,}592} = 58.5$ per cent overall efficiency.

A more accurate method of making the tests is to measure the power input for an hour, or other convenient period of time. During this period measure the output of the pump with a pitometer, or any other suitable main line meter. Keep a close record also of the discharge pressure and of the suction. The integrations on most electric meters in pumping stations cannot be read closely enough for short tests. However, the power company will furnish the number of watts consumed for each revolution of the disk, and by counting its revolutions for 10 or 20 minutes the rate of power input can be closely ascertained. Or the power company might measure the power by means of special equipment. Where more than one pump is taking power through the master meter at the same time, this latter method is the only feasible one.

To enter the tables, the total head in feet must be secured. If the pressure gauge reads in pounds, transfer the pressure to feet by multiplying the pounds of pressure by 2.31. The suction will probably be expressed in inches of mercury. Change this to feet of water by multiplying by 1.13. Also measure the vertical distance between the center of the pressure gauge and the point of suction measurement. The total head then becomes the addition of:

Discharge pressure, in feet .....
Suction, in feet .....
Vertical distance pressure gauge (Is above point of suction measurement), feet .....

Velocity head has been ignored, as it is a small factor for the relatively high heads which usually exist in water works operation.

If water is delivered to the pump under pressure, then the pump works against a head equal to the difference between the discharge pressure and the inlet pressure.

From the data secured during the test, determine the gallons delivered per kilowatt hour. As before, divide this by the theoretical value secured from the table for the head against which the pump worked. This gives the overall wire to water efficiency of the installation.

As an example, let us assume an installation where we secured the following test data:

K.W. input to motor 90.0
Rate of discharge.....51,480 gal. per hour
Number of gallons delivered per k.w.h..... 572

Table I—Gallons of Water Delivered per Kilowatt Hour Against Various Heads on Theoretical Assumption That Pump and Motor Are 100 Per Cent Efficient

H = head in feet. G = gallons per kilowatt hour

H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G
1	318,200	51	6,240	101	3,151	151	2,108	201	1,583	251	1,268	301	1,058	351	907	401	794	451	706
2	159,100	52	6,120	102	3,120	152	2,094	202	1,575	252	1,263	302	1,054	352	904	402	792	452	704
3	106,100	53	6,005	103	3,090	153	2,080	203	1,567	253	1,258	303	1,051	353	902	403	790	453	703
4	79,560	54	5,894	104	3,060	154	2,067	204	1,560	254	1,253	304	1,047	354	899	404	788	454	701
5	63,650	55	5,786	105	3,031	155	2,053	205	1,552	255	1,248	305	1,044	355	897	405	786	455	700
6	53,040	56	5,683	106	3,002	156	2,040	206	1,545	256	1,243	306	1,040	356	894	406	784	456	698
7	45,460	57	5,583	107	2,974	157	2,027	207	1,537	257	1,239	307	1,037	357	892	407	782	457	697
8	39,780	58	5,487	108	2,947	158	2,014	208	1,530	258	1,234	308	1,033	358	889	408	780	458	695
9	35,360	59	5,394	109	2,920	159	2,002	209	1,523	259	1,229	309	1,030	359	887	409	778	459	694
10	31,830	60	5,304	110	2,893	160	1,989	210	1,516	260	1,224	310	1,027	360	884	410	776	460	692
11	28,930	61	5,217	111	2,867	161	1,977	211	1,508	261	1,220	311	1,024	361	882	411	775	461	691
12	26,520	62	5,133	112	2,842	162	1,965	212	1,501	262	1,215	312	1,020	362	879	412	773	462	689
13	24,480	63	5,051	113	2,816	163	1,952	213	1,494	263	1,211	313	1,017	363	877	413	771	463	687
14	22,730	64	4,972	114	2,794	164	1,940	214	1,487	264	1,206	314	1,014	364	875	414	769	464	686
15	21,220	65	4,896	115	2,766	165	1,929	215	1,480	265	1,202	315	1,011	365	873	415	767	465	685
16	19,890	66	4,822	116	2,744	166	1,917	216	1,474	266	1,197	316	1,007	366	870	416	765	466	683
17	18,720	67	4,750	117	2,720	167	1,906	217	1,467	267	1,193	317	1,004	367	868	417	763	467	682
18	17,680	68	4,680	118	2,697	168	1,894	218	1,460	268	1,188	318	1,001	368	865	418	761	468	680
19	16,750	69	4,611	119	2,674	169	1,883	219	1,453	269	1,184	319	998	369	863	419	760	469	679
20	15,910	70	4,547	120	2,652	170	1,872	220	1,447	270	1,179	320	995	370	860	420	758	470	677
21	15,150	71	4,482	121	2,630	171	1,861	221	1,440	271	1,175	321	992	371	858	421	756	471	676
22	14,470	72	4,420	122	2,609	172	1,851	222	1,434	272	1,170	322	989	372	856	422	754	472	675
23	13,830	73	4,360	123	2,588	173	1,840	223	1,427	273	1,168	323	986	373	854	423	753	473	674
24	13,260	74	4,301	124	2,567	174	1,829	224	1,421	274	1,162	324	982	374	851	424	751	474	672
25	12,730	75	4,243	125	2,546	175	1,819	225	1,414	275	1,158	325	979	375	849	425	749	475	671
26	12,210	76	4,188	126	2,526	176	1,809	226	1,408	276	1,154	326	976	376	847	426	747	476	669
27	11,790	77	4,133	127	2,506	177	1,798	227	1,402	277	1,150	327	973	377	845	427	746	477	668
28	11,370	78	4,080	128	2,486	178	1,788	228	1,396	278	1,146	328	970	378	842	428	744	478	666
29	10,970	79	4,028	129	2,467	179	1,778	229	1,390	279	1,142	329	968	379	840	429	742	479	665
30	10,610	80	3,978	130	2,448	180	1,768	230	1,384	280	1,137	330	965	380	838	430	740	480	663
31	10,270	81	3,929	131	2,429	181	1,758	231	1,378	281	1,133	331	962	381	836	431	739	481	662
32	9,945	82	3,882	132	2,411	182	1,749	232	1,372	282	1,129	332	959	382	833	432	737	482	660
33	9,644	83	3,834	133	2,393	183	1,739	233	1,366	283	1,125	333	956	383	831	433	736	483	659
34	9,360	84	3,789	134	2,375	184	1,729	234	1,360	284	1,121	334	953	384	829	434	734	484	658
35	9,093	85	3,744	135	2,358	185	1,720	235	1,354	285	1,117	335	950	385	827	435	732	485	657
36	8,840	86	3,701	136	2,340	186	1,711	236	1,349	286	1,113	336	947	386	825	436	730	486	655
37	8,601	87	3,658	137	2,323	187	1,702	237	1,343	287	1,109	337	945	387	823	437	729	487	654
38	8,375	88	3,617	138	2,306	188	1,693	238	1,337	288	1,105	338	942	388	820	438	727	488	652
39	8,160	89	3,576	139	2,292	189	1,684	239	1,332	289	1,102	339	939	389	818	439	725	489	651
40	7,956	90	3,536	140	2,274	190	1,675	240	1,326	290	1,098	340	936	390	816	440	723	490	650
41	7,762	91	3,497	141	2,257	191	1,666	241	1,320	291	1,094	341	934	391	814	441	722	491	649
42	7,577	92	3,458	142	2,241	192	1,658	242	1,315	292	1,090	342	931	392	812	442	720	492	647
43	7,401	93	3,422	143	2,225	193	1,649	243	1,310	293	1,087	343	929	393	810	443	719	493	646
44	7,233	94	3,386	144	2,210	194	1,640	244	1,304	294	1,083	344	926	394	807	444	717	494	644
45	7,072	95	3,350	145	2,195	195	1,632	245	1,299	295	1,079	345	923	395	805	445	716	495	643
46	6,916	96	3,315	146	2,180	196	1,624	246	1,294	296	1,075	346	920	396	804	446	714	496	642
47	6,771	97	3,281	147	2,165	197	1,615	247	1,288	297	1,072	347	918	397	802	447	712	497	641
48	6,630	98	3,248	148	2,150	198	1,608	248	1,284	298	1,068	348	915	398	800	448	710	498	639
49	6,495	99	3,215	149	2,136	199	1,600	249	1,278	299	1,065	349	913	399	798	449	709	499	638
50	6,365	100	3,183	150	2,122	200	1,592	250	1,273	300	1,061	350	910	400	796	450	707	500	636

*The Pitometer Co., New York City.
[1]From WATER WORKS AND SEWERAGE.

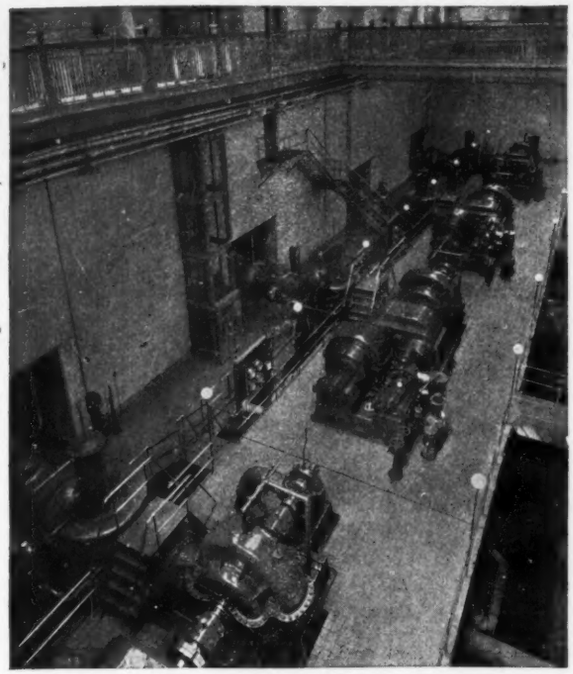
(*Continued on next page*)

DE LAVAL STEAM TURBINE COMPANY

MAIN OFFICE and WORKS: TRENTON, N. J.

SALES OFFICES

Atlanta, Ga.
Boston, Mass.
Charlotte, N. C.
Chicago, Ill.
Cleveland, Ohio
Denver, Colo.
Detroit, Mich.
Duluth, Minn.
Edmonton, Alta.
Havana, Cuba
Helena, Mont.
Houston, Texas
Kansas City, Mo.
Los Angeles, Calif.
Manila, P. I.
Montreal, Que.
New Orleans, La.
New York, N. Y.
Philadelphia, Pa.
Pittsburgh, Pa.
Rochester, N. Y.
St. Paul, Minn.
Salt Lake City, Utah
San Francisco, Calif.
San Juan, Porto Rico
Seattle, Wash.
Tulsa, Okla.
Toronto, Ont.
Vancouver, B. C.
Winnipeg, Man.
Washington, D. C.



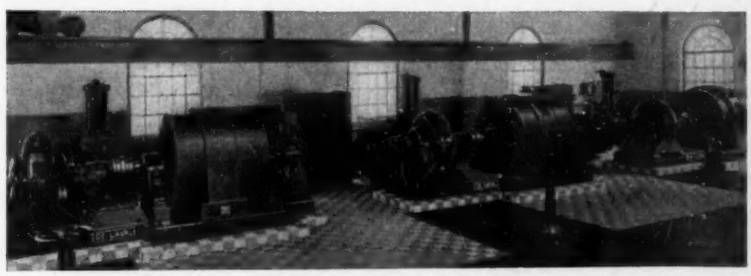
The Western Avenue Pumping Station, Chicago, containing four 75 m.g.d. De Laval compound turbine-driven pumps. The total capacity of De Laval Pumps in the Chicago waterworks exceeds a billion gallons per day

PRODUCTS

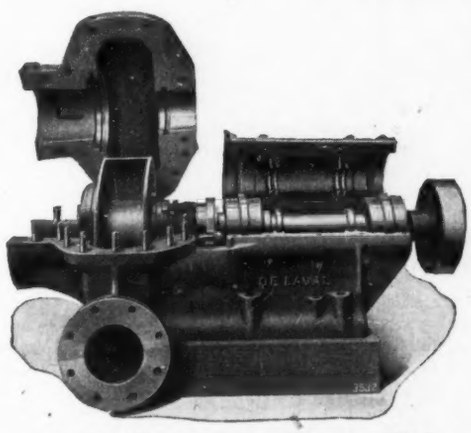
Steam Turbines; Centrifugal Pumps; Propeller Pumps; Clogless Pumps; Motor Mounted Pumps; Mixed Flow Pumps; Rotary Displacement Pumps; Centrifugal Blowers and Compressors; Helical Speed Reducing Gears; Worm Gears; Hydraulic Turbines; and Flexible Couplings.

De Laval Geared Turbine Driven Centrifugal Pumps lift water at the lowest total cost, including operating expense and capital charges on machinery, foundations and buildings. The aggregate capacity of De Laval Pumps in American water works exceeds 15 billion gallons per day, sufficient to supply the entire population.

De Laval Electric Motor Driven Centrifugal Pumps have a power limiting characteristic so that oversized motors are not necessary. The low starting torque also favors the use of self-starting synchronous motors. De Laval motor-driven centrifugal pumps have developed over-all wire to water efficiencies of 88 per cent. High efficiency is sustained by the use of LABYRINTH WEARING RINGS.

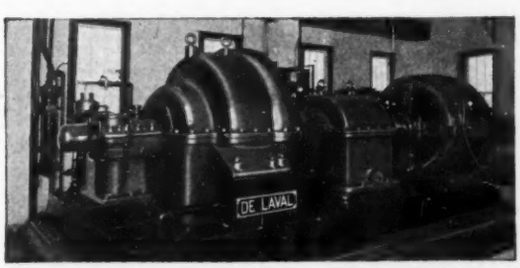


East Park Station; Philadelphia now has 20 De Laval pumping units of 445 m.g.d. aggregate capacity



De Laval Clogless Pump with covers lifted

The **De Laval Clogless Pump** for sewage has large, open, direct passages,, of correct hydraulic design. The casing is split in the plane of the shaft, making the interior quickly accessible without disturbing piping. Operating at slow speeds, these pumps compare favorably in efficiency with standard high speed, clear water pumps.



Two-stage compressor in activated sludge plant; driven at 3600 r.p.m. through De Laval speed-up gear from 1200 r.p.m. motor; 13,500 cu. ft. per min. against 6 lb. per sq. in.

De Laval Propeller Pumps running at electric motor or steam turbine speeds deliver large volumes against heads up to 40 ft., with efficiencies comparable to those of centrifugal pumps.

De Laval Centrifugal Compressors are extensively used for the activated sludge process of sewage treatment.

All De Laval apparatus is built to limit gages on an interchangeable basis; and parts subject to wear can be replaced by unskilled men, as the new parts do not require fitting. Each unit is fully guaranteed as to head-delivery and efficiency characteristics and is thoroughly tested before it leaves our works.

Pressure	146 lb.	or 337 ft.
Suction	15 in.	or 17 ft.
Difference in gauge elevation	1 ft.	1 ft.
Total head		355 ft.
Theoretical discharge 355 ft. head (tables)	897 gal.	
Overall efficiency	$\frac{572}{897}$ = 64 per cent	

Provided a suction gauge is not available an approximation may be secured by measuring the vertical distance from the level of water in the clear well to the center of the pressure gauge, adding to this measured distance about one foot for loss in bends, etc.

Results of Checking Efficiency

The solution of each instance of inefficient operation is a problem in itself. No hard and fast rule for procedure can be given. In the case cited of obsolete design, the economical procedure was to replace the pump with one of modern design, keeping the old unit as a standby. In other instances, a change in the impeller will often return the pump to high efficiency. In one case, where a multiple stage pump was working against a high head, it was found that its inefficiency was caused by a defective gasket between the upper and lower parts of the pump case. This permitted the water to flow back from the higher to the lower stages, thereby decreasing both the rate of discharge and the efficiency. A new gasket was all that was necessary to solve the difficulty. In another instance, it was found that some of the ports had become plugged with wood, probably when a filter bed had broken three years previously. At least once, an impeller was found loose on the shaft.

About two years ago, an instance was uncovered where an apparent inefficiency was due to the power meter being set high. As soon as the test figures were in, the striking thing was not so much the low efficiency indicated, as the fact that the motor was apparently taking power at a rate which would have caused it to "burn up" from over-loading.

This list could be prolonged almost indefinitely, but it is believed that enough illustrations have been given to show the value of continuous checks. Many progressive operators show on their monthly or weekly reports the number of gallons pumped for the period for each kilowatt hour of power consumed. This is a splendid practice. Whenever our company, in making these tests, has found a low efficiency indicated, our experience has shown that the power companies and the pump manufacturers are most willing to cooperate in restoring the plant to efficient operation.

Assuming that the motor is about 90 per cent efficient, the following overall wire to water efficiencies may be expected from centrifugal pumps of good design:

g. p. m.	Per cent
200	49
400	54
600	58
800	60
1000	63
1500	67

More expensive pumps of best design will often show values of three to five per cent higher than the above figures.

In order to illustrate how the table can be used to compute probable savings to result from the substitution of a more efficient unit for an existing inefficient one, let us assume that 1,000 g.p.m. are being pumped against a total head of 200 ft., and a discharge of only 796 gal. per k.w.h. is secured. This gives us $\frac{796}{1592}$ = 50 per cent efficiency. Should this installation be replaced by one capable of an overall efficiency of 65 per cent, we would get 1,592 × 65 per cent = 1,035 gal. per k.w.h.

With an assumed monthly pumpage of 30,000,000 gal., it would require, with the original installation, $\frac{30{,}000{,}000}{796}$ = 37,676 k.w.h. to pump the water.

With the proposed more efficient installation it would require $\frac{30{,}000{,}000}{1{,}035}$ = 28,986 k.w.h.

This is a saving of 8,690 k.w.h., or 23 per cent, in the actual power consumption. There is also a similar decrease in the demand rate. The pumping rate of 1,000 g.p.m. equals 60,000 g.p.m.

$$\frac{60{,}000}{796} = 75 \text{ k.w. demand rate}$$

and

$$\frac{60{,}000}{1{,}035} = 58 \text{ k.w. demand rate.}$$

This is a decrease of 17 k.w. or 23 per cent in the demand rate. Both the demand rate and the actual consumption of power are therefore decreased in the same proportion. If the power cost averages 2 ct. per k.w.h., the reduction amounts to 8,690 × 0.02 = $173.80 per month, or $2,085.60 per year.

A word of warning may not be amiss here. While the large pumps are more efficient than the smaller ones, pumps larger than actually required should not usually be used. Often the additional friction loss due to higher velocity will offset the increased efficiency, and the higher demand charges will boost the total bill considerably.

Assume an installation which consumes 12,000 k.w.h. per month and which has a demand schedule as follows:

5,000 k.w.h. @ 0.030c	$150.00
5,000 k.w.h. @ 0.026c	130.00
2,000 k.w.h. @ 0.012c	24.00
Total	$304.00

If we use a smaller installation with half this demand rate we might use 13,000 k.w.h. per month to pump the same amount of water, but the total bill would be less:

2,500 k.w.h. @ 0.030c	$ 75.00
2,500 k.w.h. @ 0.026c	65.00
8,000 k.w.h. @ 0.012c	96.00
Total	$236.00

This is a saving of $68.00 per month although more power is actually consumed. And, after all, the object in securing increased efficiency is to pump more water per dollar.

Measuring Output of Water

Table I previously given has another use. Many plants, especially smaller ones, have no master meters. With the old displacement type pump it was possible to secure the approximate amount of water pumped by installing a pump stroke counter and multiplying the number of strokes by the discharge in gallons per stroke. If the pump were permitted to get into a state of disrepair, this measurement was apt to be in error, but if the pump were kept in good condition it was reasonably accurate. The method about to be outlined for obtaining the output of water from electrically operated centrifugal pumps has possibly a degree of accuracy comparable to the pump counter method.

From the efficiency curve furnished with the pump, determine the pump efficiency for the head under which the pump operates. The curve will show the pump efficiency only. The combined pump and motor efficiency, the so-called wire to water efficiency, will be about 90 per cent of the efficiency shown for the pump alone. From Table 1 secure the theoretical gallons per kilowatt hour for the head under which the pump is operated. Multiply this by the overall wire to water efficiency just secured. This gives the number of gallons per kilowatt hour the pump should deliver. Multiply this by the total number of kilowatt hours used over any given period of time and the result should be the number of gallons pumped over the same period. If a curve for the pump is not available and if the manufacturer cannot supply one, approximate results can be obtained by using the efficiencies previously given in this paper. To illustrate:

Assume a pump with an efficiency of 65 per cent operating at a total head of 200 ft. Then 90 per cent of 65 would give an overall wire to water efficiency of 58.5 per cent. If the installation were 100 per cent efficient, Table 1 indicates the discharge would be 1,592 gallons per kilowatt hour. With an overall efficiency of 58.5 per cent the discharge would be 1,592 × 58.5 per cent, or 931 gal. If the power consumption for the month be 20,000 kilowatt hours, then the total pumpage becomes 20,000 × 931 or 18,620,000 gal. for the month.

While this method of computing pumpage will not, as a rule, give results as satisfactory as those secured from a master meter, it does give a close approximation in instances where a master meter is not available. As a matter of fact, in one instance where this method was used to check the master meter, it was found that it would have been impossible for the pump to have delivered the water shown on the master meter unless the installation had an efficiency of about 125 per cent. This, of course, would be impossible. Whenever a pump installation gives an efficiency over 100 per cent, the secret of perpetual motion will have been discovered. In the case just cited, the master meter was about 100 per cent fast.

In outlining the tests in this paper it has not been intended to supplant the more detailed methods used by professional engineers, but to make available to the average water works operator a method of checking which will give reasonably accurate results.

BAILEY METER COMPANY

1072 Ivanhoe Road, CLEVELAND, OHIO

BOSTON NEW YORK ST. PAUL BUFFALO KANSAS CITY PITTSBURGH HOUSTON ERIE DENVER CINCINNATI SAN FRANCISCO CHICAGO MILWAUKEE

BAILEY METER COMPANY LIMITED, Montreal, Canada

METERS, GAGES and CONTROLLERS for SEWAGE TREATMENT and WATER SUPPLY

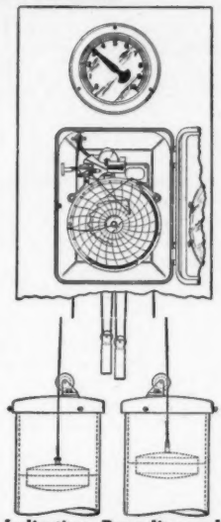
STANDARD BAILEY REGISTERS

Open Float Type Meters—The flow of sewage, sludge, dirty water or other liquids in pipe lines is accurately measured by the Bailey Float Type Meter using a Venturi Tube, flow nozzle or orifice as the primary producing device.

This meter is of the open float tube type with differential gearing and cam designed so that the register operates in direct proportion to the rate of flow.

Standard Bailey indicating, recording and integrating instruments are used; charts being 12″ in diameter and uniformly graduated. These instruments may be either wall or panel mounted and may be furnished on self-supporting panels if desired.

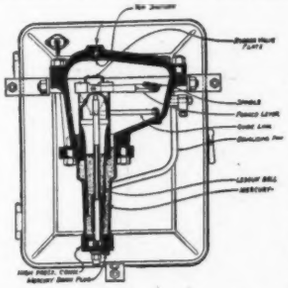
Bailey float type meters are simple, sturdy, neat-appearing and extremely flexible. Capacities may be changed by simple adjustments within the register and remote instruments can be operated from the main register if desired.



Indicating, Recording and Integrating open float tube type Register.

Bailey Flume Meters—Surprising low head losses result from the measurement of water or sewage in open channels when Bailey Flume Meters are used. These simple self-cleaning meters indicate, record and integrate on standard Bailey registers. Instruments may be placed in remote locations by the addition of the Bailey Synchro-Meter transmission system.

Bailey Weir Meter—Highly accurate results in the measurement of sewage or water flowing in open channels are obtained by the use of the Bailey Weir Meter.



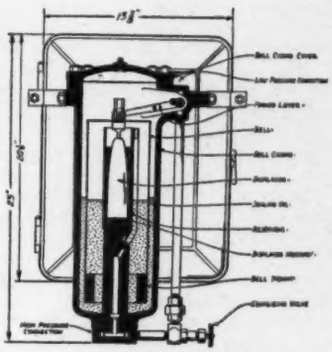
Section through flow mechanism of Ledoux Bell type Register.

Complete flexibility in the location of the standard Bailey registers of this meter may be provided by the Bailey Synchro-Meter transmission system.

Bailey Fluid Meter—The flow of steam, liquids and gases in pipe lines at high or low pressures can be accurately measured by the Bailey Fluid Meter. A Venturi Tube, flow nozzle, or orifice is used as the differential producing device and the meter indicates, records and integrates on the standard Bailey register previously described. Remote recorders may be provided by Bailey Synchro-Meter transmission which operates electrically on alternating current.

In addition to the rate of flow, this meter may also record pressure, temperature or liquid level on the same chart.

Described in bulletin No. 301.



Section through flow mechanism of Air Meter

Air Meters—These meters measure Air Flow in main lines and in individual lines to aeration tanks.

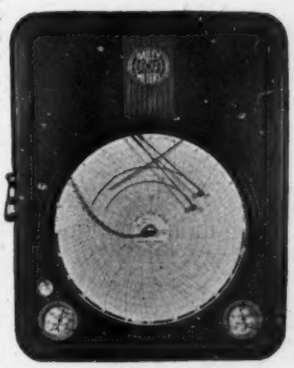
The register is similar in appearance to the Ledoux bell type, and the flow mechanism is designed to operate on a maximum differential pressure of 8-in. of water. *Described in bulletin No.* 301.

Remote Registers—Bailey Telemetering systems make it possible to operate remote indicating, recording or integrating registers, which may be installed at a distance from the direct connected unit. These registers may measure flow in individual lines, total flow, liquid level, pressure and other factors.

Venturi Tubes—Standard Bailey Designs include a complete range of Venturi tubes and other primary elements suited to the measurement of sewage, sludge and water. The selection of a suitable primary element is governed by such factors as capacity required, type of flanges, pressure loss allowable and character of fluid to be metered.

Controllers — Bailey Controllers utilize standard Bailey Meters and Recorders as the basic measurement source for the automatic control of factors, such as flow, ratio, pressure and liquid level. They are operated by compressed air at approximately 35 lbs. pressure and match perfectly with other Bailey gages and registers.

Bailey control is fully automatic, dependable and exceptionally flexible. *Ask for Bulletin No.* 101.



Bailey Recorder—Controller.

Bailey Registers measuring Sewage, Sludge and Air in an operating gallery at Easterly Sewage Treatment Works, Cleveland, Ohio.

COMPUTING HORSEPOWER FROM REVOLVING WATT-HOUR METERS

A simple method of accurately measuring power consumption is of general interest to the owner or operator of any electrically driven pump. A periodical record of the power consumption, capacity of the pump, and the measurement of the pumping level assists in maintaining operation at maximum efficiency and gives an indication as to the proper time for reconditioning or modernizing the installation.

The power consumption is measured by the Watt-Hour Meter, usually located on the switchboard in the pump house adjacent to the motor. Large units require current and/or potential transformers, so that the watt-hour meter reading must be multiplied by the ratio of these transformers to obtain the correct measurement of power consumption of the motor.

A motor which draws 200 amp. at 440 volts may be metered through current transformers rate 200 amp. primary and 5 amp. secondary, so that 5 amp. would pass through the watt-hour meter. No potential transformers being used, the watt-hour meter reading, multiplied by the ratio of 200 to 5, would give the amount of power in the main circuit.

Asssuming that a motor draws 600 amp. at 2300 volts, potential as well as current transformers are required. If the ratio is 60 to 5 amp. on the current, and 2300 to 115 on the potential transformers, the watt-hour meter reading multiplied by the ratio of 60 to 5 and in addition, by the ratio of 2300 to 115, will give a true measure of the power consumption in the main circuit. The correct ratio is usually stamped on a brass nameplate attached to the transformer.

Disk constants and multipliers for practically all modern watt-hour meters now in use for single and three phase, 110-220-440 volts are shown in the chart below.

Use of Chart

First determine the make, type, volts and amp. of the meter. If no current or potential transformers are used, refer to the chart and determine M value for the meter. The M × r.p.m. of disk = hp. input to motor for example, a meter, G.E., type D-3, 220 volt, 15 amp., K = 4.0, M = .3217, number of revolutions of disk in one minute = 20. Then .3217 × 20 = 6.434 h.p. input to motor.

As another example consider an installation where current transformers having a ratio of 20 to 1 are used. Meter, Westinghouse type OA, 220 volt, 5 amp., K = 1⅓, M = .1027, number of revolutions of disk in one minute = 21. Then, .1072 × 21 × 20 = 45.02 h.p. input to motor.

Disk constants K are included in the accompanying chart because occasionally the manufacturer's nameplate has been removed, in which event the constant K is marked on the meter. To determine the M value in such cases, find a K in the table corresponding to that on the meter in question. The M applying will be the one adjacent to and on the right of this K.

Definitions:

K—A constant which represents the number of watt-hours passed through the meter while the disk makes one revolution.

M—A factor which, when multiplied by the number of revolutions of the disk, in one minute, gives h.p. input to motor.

Mathematically, $M = \frac{K \times 60}{746}$

The h.p. values expressed above relate to input to motor. The rating of motors is in terms of h.p. output. Therefore, the h.p. output or brake h.p. is determined by multiplying the h.p. input by the motor efficiency, which can be obtained from the motor manufacturer.

Chart of Constants and Multipliers

For Use in Determining KW Input, HP Input or BHP from Revolutions of Watthour Meter Disks

110 Volt—Single Phase

Amp.	General Electric 1		General Electric 1-10		General Electric 1-14		General Electric 1-16		Sangamo H		Westinghouse B, C, OA, OB	
	K	M	K	M	K	M	K	M	K	M	K	M
5	.3	.0241	.25	.0201	.3	.0241	.6	.0483	5/24	.0168	⅓	.0268
10	.6	.0483	.5	.0402	.6	.0483	1.2	.0965	5/12	.0335	⅔	.0536
15	1.0	.0804	.75	.0603	.9	.0724	1.8	.1448	5/8	.0503	1	.0804
25	1.5	.1206	1.25	.1005	1.5	.1206	3.0	.2413	2 5/24	.0838	1⅔	.1340
50	3.0	.2413	2.5	.2011	3.0	.2413	6.0	.4826	2 1/12	.1676	3⅓	.2681

220 Volt—Single Phase

Amp.	General Electric 1		General Electric 1-10		General Electric 1-14		General Electric 1-16		Sangamo H		Westinghouse B, C, OA, OB	
	K	M	K	M	K	M	K	M	K	M	K	M
5	.6	.0483	.5	.0402	.6	.0483	1.2	.0965	5/12	.0335	⅔	.0536
10	1.25	.1005	1.0	.0804	1.2	.0965	2.4	.1930	5/6	.0670	1⅓	.1072
15	2.0	.1609	1.5	.1206	1.8	.1448	3.6	.2895	1 1/4	.1005	2	.1609
25	3.0	.2413	2.5	.2011	3.0	.2413	6.0	.4826	2 1/12	.1676	3⅓	.2681
50	6.0	.4826	5.0	.4021	6.0	.4826	12.0	.9651	4 1/6	.3351	6⅔	.5362

110 Volt—Three Phase

Amp.	General Electric D-3		General Electric D-6 & D-7		General Electric D-14		Sangamo H		Westinghouse C, OA, OB, RO.	
	K	M	K	M	K	M	K	M	K	M
5	.6	.0483	.6	.0483	1.2	.0965	5/12	.0335	2/3	.0536
10	1.25	.1005	1.2	.0965	2.4	.1930	5/6	.0670	1 1/3	.1072
15	2.0	.1609	1.8	.1448	3.6	.2895	1 1/4	.1005	2	.1609
25	3.0	.2413	3.0	.2413	6.0	.4826	2 1/12	.1676	3 1/3	.2681
50	6.0	.4826	6.0	.4826	12.0	.9651	4 1/6	.3351	6 2/3	.5362

(Continued on next page)

220 Volt—Three Phase

Amp.	General Electric D-3		General Electric D-6 & D-7		General Electric D-14		Sangamo H		Westinghouse C, OA, OB, RO.	
	K	M	K	M	K	M	K	M	K	M
5	1.25	.1005	1.2	.0965	2.4	.1930	5/6	.0670	1 1/3	.1072
10	2.5	.2011	2.4	.1930	4.8	.3861	1 2/3	.1340	2 2/3	.2145
15	4.0	.3217	3.6	.2895	7.2	.5791	2 1/2	.2011	4	.3217
25	6.0	.4826	6.0	.4826	12.0	.9651	4 1/6	.3351	6 2/3	.5362
50	12.5	1.005	12.0	.9651	24.0	1.930	8 1/3	.6702	13 1/3	1.072

440 Volt—Three Phase

Amp.	General Electric D-3		General Electric D-6 & D-7		General Electric D-14		Sangamo H		Westinghouse C, OA, OB, RO.	
	K	M	K	M	K	M	K	M	K	M
5	2.5	.2011	2.4	.1930	4.8	.3861	1 2/3	.1340	2 2/3	.2145
10	5.0	.4021	4.8	.3861	9.6	.7721	3 1/3	.2681	5 1/3	.4289
15	7.5	.6032	7.2	.5791	14.4	1.158	5	.4021	8	.6434
25	12.5	1.005	12.0	.9651	24.0	1.930	8 1/3	.6702	13 1/3	1.072
50	25.0	2.011	24.0	1.930	48.0	3.861	16 2/3	1.340	26 2/3	2.145

hp. Input = "M" × Revolutions per minute of Disk

hp. Input = "K" × Number of Revolutions × 3600.

Sec. × 746

Important—Where instrument transformers are used, be sure that figure computed from revolutions of disk and table be multiplied by ratio of instrument transformers.

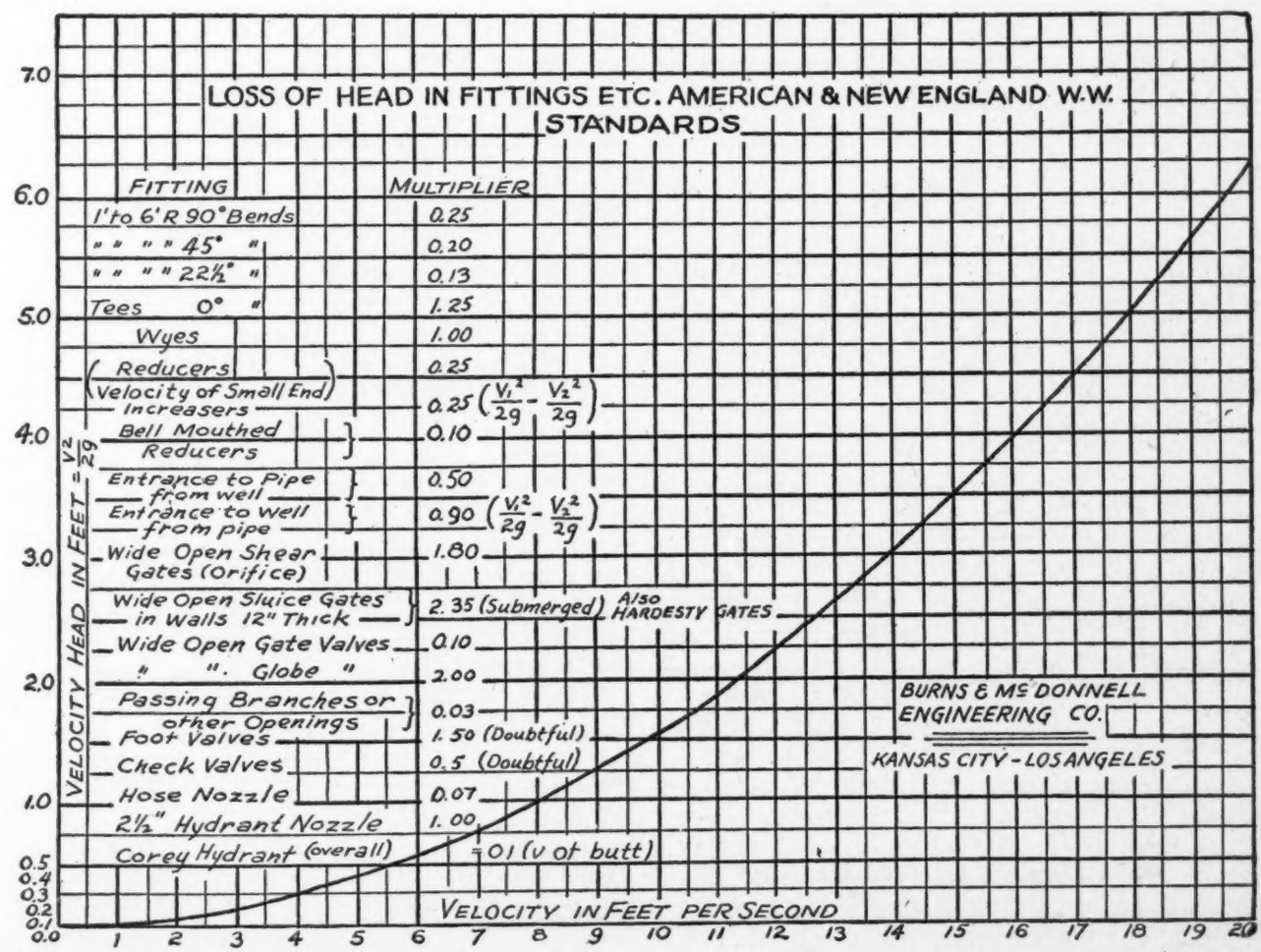
(From Byron-Jackson Bulletin, "Deep-Well Turbine Pumps.")

Loss of Head Through Valves and Fittings

(Burns and McDonnell)

To determine loss of head—Assume flow (Q) to be 5 cu. ft. sec. through a fitting of 12 inch diameter. From Q—AV the velocity (V) = 6.4 ft. per sec. From the chart, velocity head $\frac{V^2}{2g} = 0.7$ ft. Applied to 90 degree bend head loss is $0.25 \times 0.7 = 0.18$ ft. For a tee $1.25 \times .7 = 0.87$ ft.

(Note—Recent correspondence with the producers of this chart cites valves for check valves far in excess of the 0.5 indicated.—*Ed.*)



RATING AND SAMPLING WELLS BY AN IMPROVED METHOD

By PAUL F. HOWARD, M.S.*

Consulting Engr., Boston, Mass.

It is oft-times desired and of importance to ascertain the quantity and quality of water yielded by an individual driven well connected to other wells of a water system. Experience has shown that analyses of samples of water taken from individual wells by means of a hand pitcher-pump give false and meaningless results, especially in relation to the iron content. Likewise the yield of an individual well by means of separate pumping furnishes but little if any information as to the yield of the individual well when ganged together into a common system.

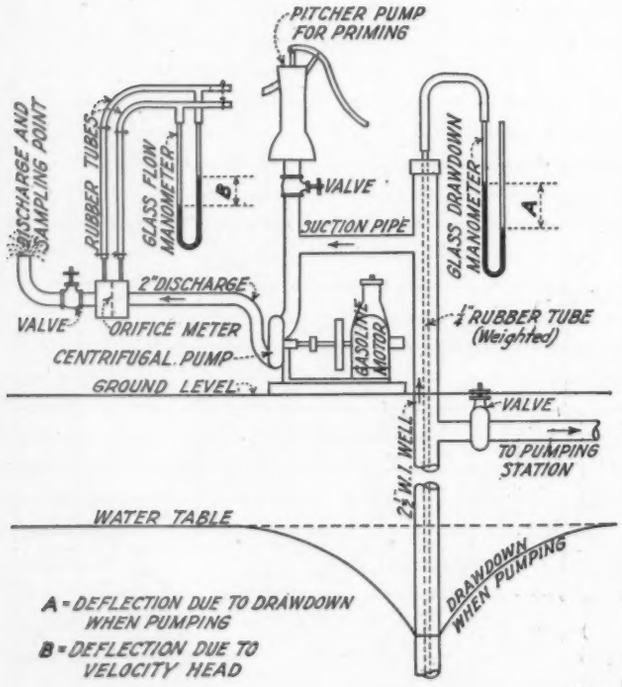
The writer's firm was engaged to investigate a water supply from about 90 driven wells. During the course of the work it became desirable to determine the yield of each individual well and the iron content of the water from each individual well under normal operating conditions. This was done by a device which we have called a Well Rater and Sampler. The device (see cut) was connected to the top of the well by a 2½ inch wrought iron pipe about 2½ feet long. At this point a 1¼ inch centrifugal pump was connected by the proper fittings and discharged through a 2 inch pipe. On the suction pipe a hand pump was attached to prime the pump. A 2 inch orifice flow meter was inserted in the discharge line and by means of a manometer the rate of flow was determined. The amount of the draw-down of the well, when connected to the well field, was determined by means of a mercury U tube connected to a small tube attached to the well cap, the tube extending into the well to a depth sufficiently great so that the end was at all times below the level of the water-table outside of the well.

Before the Well Rater and Sampler was connected to the well the permanently installed valve on the suction line was closed. After the device was connected this valve was opened and the well was observed under actual working conditions—i.e., while it was being pumped along with the other wells by the large pump in the pumping station. The drawdown was revealed by the reading of the manometer connected to the tube in the well and recorded. Thereafter, the permanently installed valve was closed and the centrifugal pump started, the rate of pumping being controlled by a valve on the discharge line. As the discharge increased the drawdown increased, thus producing a deflection on the manometer. When the manometer reading was the same as that already observed under the actual working conditions, as just described, the output of the well was assumed to be the same. The quantity being pumped was then determined by observing the deflection of the flow manometer on the pump discharge line. The results represented the actual amount of water that the well was contributing from the field as a whole when under *actual* pumping conditions. Samples of water for analyses, then taken at the point of discharge, were considered truly representative samples.

By careful operation of the valve at the discharge end of the pipe the yield of the well was brought gradually up to the original yield at the beginning of pumping. Thereby higher velocities than usual or ordinary in the pipe well were provided. Any excess velocities would, of course, free scale, rust and other matter and give false samples. The flow manometer in this particular instance was connected to the 2 inch orifice flow meter. [The liquid used to determine the differential pressure can be of any specific gravity desired depending upon the rate of flow to be measured. The most common is mercury for high flows and carbon tetrachloride, Specific Gravity 1.60, for low flows.]

One side of the mercury U tube was connected to the tube in the well and filled with water from the surface of the mercury to the water level in the well, care being taken to remove all air. The other side of the U tube was left open to the atmosphere.

*Whitman and Howard, Engs., Boston, Mass.



WELL RATER AND SAMPLER

The Hook-Up of the Well Rater and Sampler

A Specific Case

The following specific example will serve as an illustration. After the Well Rater and Sampler had been properly set up and connected to a well the mercury U tube was connected to the tube in the well. There was an initial deflection of mercury of 3 inches which represented a water column of 40½ inches, the distance from the water table to the mercury surface of the U tube. After an equilibrium had been reached the well was connected to the field and the mercury in the U tube deflected an additional amount corresponding in general to the distance the water table dropped outside of the well and specifically to the drop in pressure in the well. In this case the total deflection was 4¼ inches or a difference in deflection of 1¼ inches which equal 17 inches of water as the drawn down within the well.

The well was then shut off from the other wells and the small test pump started. The discharge valve on the pump was then opened slowly, increasing the yield of the well until the drawdown deflection of mercury showed 4¼ inches. After this point was reached the flow manometer was observed to have a deflection of 1⅝ inches of mercury which on this meter represented a flow of 20.1 gallons per minute.

The yield of the various wells in relation to the drawdown was plotted on arithmetic paper and the yield of each well was found to be directly proportional to its drawdown. The yield of the various wells varied from 1 to 25 gallons per minute and the drawdown varied from 5½ to 26 inches.

This device has been made use of in installing new driven well fields. By its use we have been able to predict reasonably well the draw down or vacuum to be expected in a system of driven wells and to eliminate uneconomic wells, which have a low yield in relation to the drawdown. Also with open end wells it has been possible to determine at what yield a well will throw sand sufficiently to result in filling up by sand. The equipment will probably be found to have other uses also.

Acknowledgment—The above paper was presented before the New England Water Works Association, at Providence, R. I., Sept. 19, 1935, and appeared in WATERWORKS & SEWAGE for December, 1935.

ELIMINATING SURGE TROUBLES ON PUMP DISCHARGE LINES*

By D. M. RADCLIFFE

Engineer, U. S. Engineers' Office, Washington, D. C.

The purpose of this article is to relate a practical means of preventing dangerous surges and water-hammer in water service pipe lines.

There are several means of preventing surges in pipe lines, the best known of which is the surge tank. In most water supply systems it is not practical to provide surge tanks and therefore some other means must be employed if excessive surging is to be eliminated.

A common cause of dangerous water-hammer or surge in pipe lines of water supply systems is failure of the electric power input to motor driven pumping units. This sudden stop in pumping sets up a series of pressure waves or surges in the discharge pipe line. Much has been published with respect to water-hammer and its effects on pipe lines, therefore this article will discuss briefly a practical means of eliminating surge or water-hammer conditions. The method described is in satisfactory operation on the Washington Aqueduct in the city of Washington, D. C.

The Dalecarlia Pumping Station is equipped with nine synchronous motor driven centrifugal pumping units of 10 and 20 m.g.d. capacities. Three discharge pipe lines extend from the station to service reservoirs. One is a 48-inch pipe line, 12,350 feet in length with 110 feet working head; one a 36-inch line, 8,900 feet in length with 220 feet working head; one a 36-inch line, 15,950 feet in length with 340 feet working head. Three pumps are connected into each of these three lines.

Following accepted practice quick closing check valves had been installed in each of the pump discharge lines. Electric power failures, which occur several times each year, proved the cause of excessive and dangerous surges of water-hammer in the discharge lines. Records of the surges were taken on high-speed pressure charts and it was found that the maximum surge pressures recorded were 175 per cent above normal working pressure on each line.

Rotary Plug Type Check Valves Installed

After the pumping station had been in opertion for approximately three years, it was decided to install check valves which would reduce to a minimum the loss of head through such valves. The new valves installed are of the rotary plug type and hydraulically operated. These are equipped with an adjustable timing feature to provide means of regulating the speed of closing upon pump shut-down or failure of electric power. Timing tests were made on the new valves to determine, if possible, a closing period which would limit pipe line surges to safe values. A number of closing periods, varying from one second to fifteen seconds, were tried. It was not permissible to employ closing periods in excess of fifteen seconds because a reverse flow of water through the pumps would take place and rotate the units backward at high speed. Since the pumps are not designed for reverse rotation this condition was considered unsafe and time of valve closing was limited to a maximum of fifteen seconds. In the series of closing period tests made, it was found that a five second period produced the best results, but the surge was still 100 per cent above normal working pressure. Unless the check valve can be left open until a surge is dissipated and then closed slowly, it is necessary to close the valve before the first supernormal return wave reaches the station or valve. In the case of the Dalecarlia Station, the first

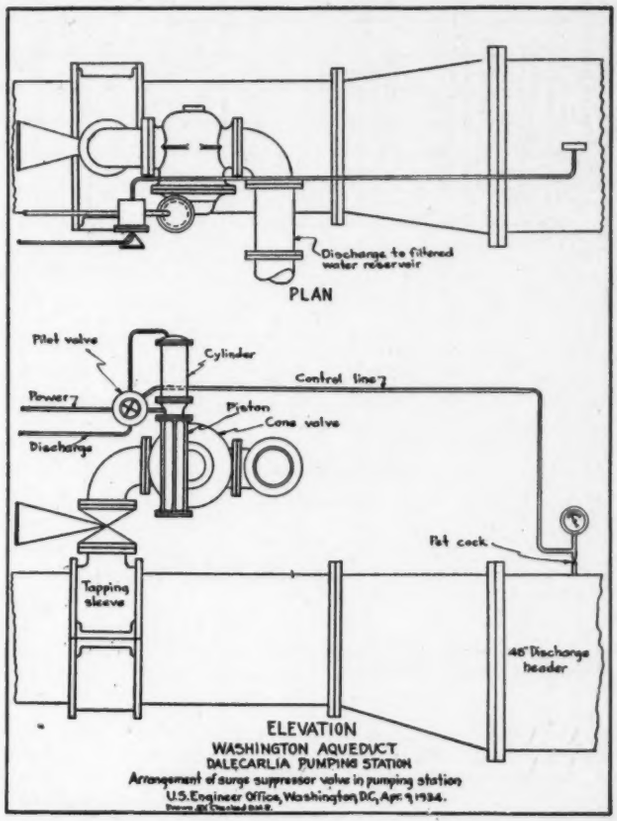


Fig. 2.—Sketch to Show Arrangement of Tapping Sleeve and Surge Relief Valves

*From WATER WORKS AND SEWERAGE, May, 1934.

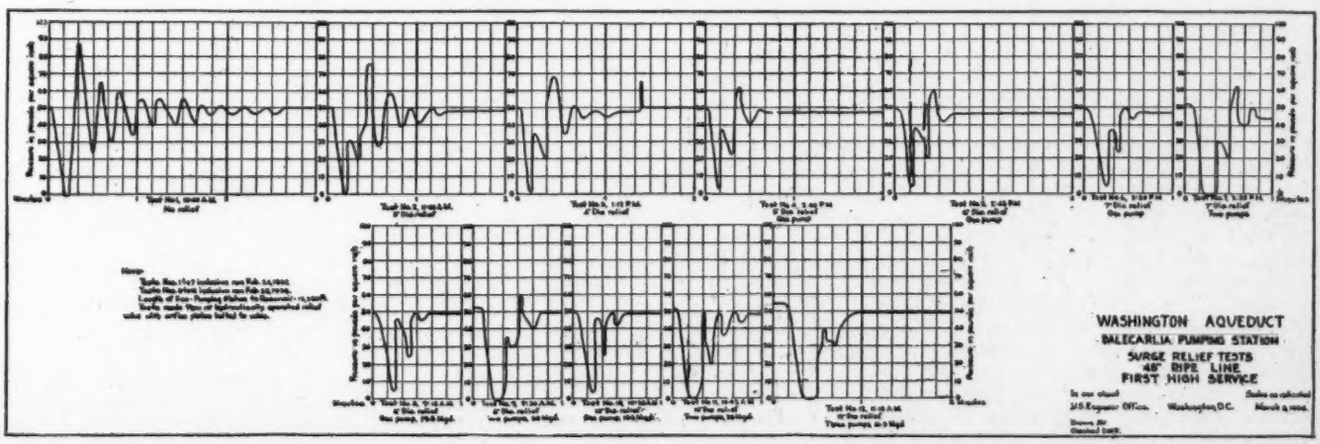


Fig. 1.—Results from Surge Relief Experiments, Employing Various Sizes of Relief Orifice

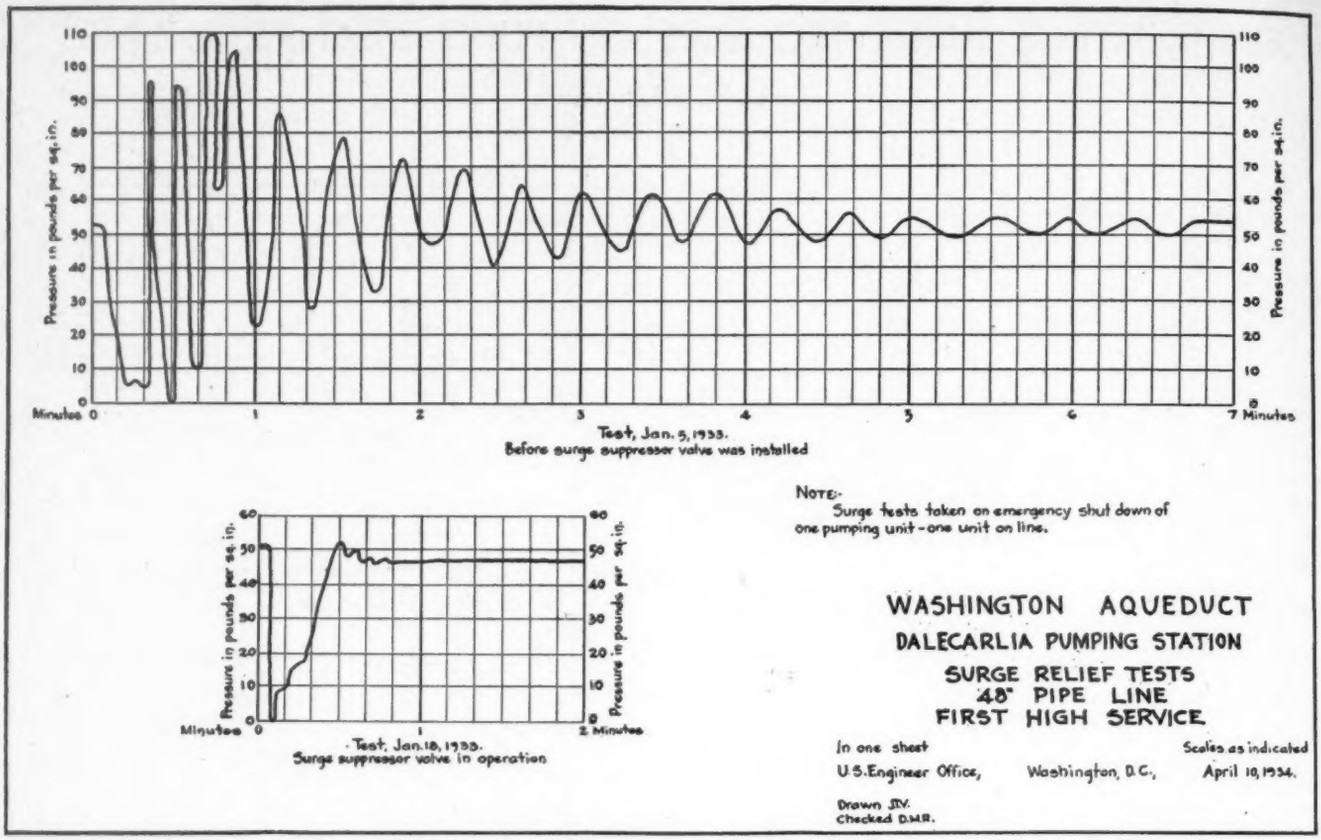

Pressure in pounds per sq. in.
Minutes
Test, Jan. 5, 1933.
Before surge suppressor valve was installed
Test, Jan. 18, 1933.
Surge suppressor valve in operation
NOTE:
Surge tests taken on emergency shut down of one pumping unit - one unit on line.
WASHINGTON AQUEDUCT
DALECARLIA PUMPING STATION
SURGE RELIEF TESTS
48" PIPE LINE
FIRST HIGH SERVICE
In one sheet
Scales as indicated
U.S. Engineer Office, Washington, D.C., April 10, 1934.
Drawn JIV.
Checked D.M.R.

Fig. 3.—Charts Illustrating Surge Conditions Before and After Installation of Cone Type Relief Valves on Discharge Lines

supernormal wave reached the station seven seconds after power failure. The results obtained by valve timing were therefore not considered satisfactory because these valves must protect pipe lines of concrete construction which were not designed to withstand the surge pressures encountered.

Further Studies on Surge Relief

Investigations of several methods of surge suppression in pipe lines were then made. It was decided to provide a relief valve on each pipe header in the pumping station. To make the installation it was necessary to provide an outlet from each of the three pump-discharge lines. This was accomplished by installing "Smith" tapping sleeves (Fig. 2) with 10 inch outlets. A 10-inch gate valve was bolted to each sleeve to provide emergency shut-off. The discharge from each surge relief valve was carried into the filtered water reservoir to prevent waste of purified water.

Before deciding upon size of valves to be used, calculations and field tests were made to arrive at the size of relief required. The field tests consisted of a series of surge tests relieved through different sizes of openings. This was done by providing a 12 inch valved opening on one of the pumping station headers. A series of tests was then made under variable pumping conditions with the several orifice plates bolted on the valve. The valve was of the quick opening, hydraulic type, manually controlled. A signal system was installed to insure proper timing of test valve opening. The field tests included surge relief through openings 2, 4, 6, 8, 10 and 12 inches in diameter. It was found that the 2 and 4-inch openings had very little effect in damping the supernormal surge pressure. The 6-inch opening did not damp the first supernormal wave but did damp out the succeeding waves. The 8-inch opening entirely damped or eliminated all supernormal waves. From the results obtained in the field tests it was decided to install 10-inch surge relief valves on each of the pump discharge lines. The chart (Fig. 1) shows the results of the tests made with the orifice plates under variable pumping conditions.

Automatic Cone Relief Valves Installed

The surge suppressor or relief valves installed are of the hydraulically operated, rotary plug type (Fig. 2), manufactured by the Automatic Cone Valve Company, now a division of the Chapman Valve Company. Since the valves meet open when the pressure drops in the pipe lines it was necessary to supply water pressure for valve operating from an independent source of supply. A 60-gallon residential supply water system was installed to insure an unfailing supply of water pressure to the three surge relief valves. The valves operate in the following manner: the normal pressure of the pipe line operates against a spring diaphragm pilot valve which admits control water pressure to the "closing" end of the hydraulic piston.

This holds the surge relief valve in the closed position. When a power failure occurs, the water in the pipe line flows away from the pumping station causing a subnormal wave in the line. This results in low pressure against the control diaphragm, which allows a spring to operate the pilot valve, which in turn allows high pressure control water to flow to the "opening" end of the hydraulic piston which opens the main surge relief valve. The opening action is very rapid, the entire operation requiring only from 1.5 to 2 seconds. The average duration of the first sub-normal wave in the Washington lines is approximately 8 seconds, thus the surge relief valve is wide open before the first super-normal return wave reaches the station. With the surge relief valve open, all succeeding supernormal waves are dissipated through the open valve. The pipe line now assumes a penstock condition and the surge relief valve must be closed very slowly in order to prevent setting up penstock surges. This is done by limiting the flow of control water to the "closing" end of the hydraulic piston. For successful results it was found that a 2-second opening and 2.5-minute closing of the surge relief valves entirely eliminated water-hammer or surges in the respective pipe lines.

Results

During the period of service since these surge relief valves have been in operation in the Dalecarlia Pumping Station several power failures have occurred. High speed pressure charts indicate, however, that pipe line surges have been entirely eliminated as indicated by typical records pictured in Fig. 3.

THE ELIMINATION OF CHECK VALVE SLAM

By H. K. PALMER*
Los Angeles, Cal.

The slamming of check valves when pumps are stopped constitute a source of annoyance and often of expense to water works or sewage works, and allied institutions. Many check valves have an annoying habit of slamming when it is least expected, while others placed on long lines may close quietly. Too sudden closing may easily cause a rupture in a pipe line, a feature which may be eliminated by inclusion of a large air chamber which will eliminate sudden pressure on the pipe but may cause such an abrupt closing of the valve as to crack the flap.

Check valve slam produced by a surge in the water column causes water hammer, with its consequent damage. When a pump suddenly stops, the water tends to continue in motion due to its momentum, and the gage pressure drops to zero. The force tending to stop the motion of the water is proportional to the static head on the pump and such force produces a negative acceleration in the water column according to the formula:

$$F = Ma$$

where: F = Force producing acceleration; M = Mass of water; a = Acceleration.

Letting: A = Area of pipe, square feet; L = Length of pipe in feet; g = Acceleration due to gravity (32.2); w = Weight of a cubic foot of water (62.4 lbs.); h = Static head on the pump; Hf = Friction head; H = Total head; t = Time in seconds; v = Velocity in pipe:

One may: compute the force producing acceleration as being

$$F = h\ A\ w$$

And, the mass of water is found to be

$$M = \frac{A\ L\ w}{g}$$

Then:

$$h\ A\ W = \frac{A\ L\ w}{g}\ a$$

Or

$$a = \frac{h}{L}\ g \qquad \text{(See Figue 1)}$$

If v is the velocity in the pipe before the pump stops, the time (in seconds) required to bring the water to a stop will be

$$t = \frac{v}{a}$$

If the flap can come to its seat in (t) seconds or less, it is obvious that the water cannot move backwards and as the flap is moving against the stream it will be cushioned. On the other hand if the flap does not have time to become seated within (t) seconds, the water will start backwards and the valve will close with a slam.

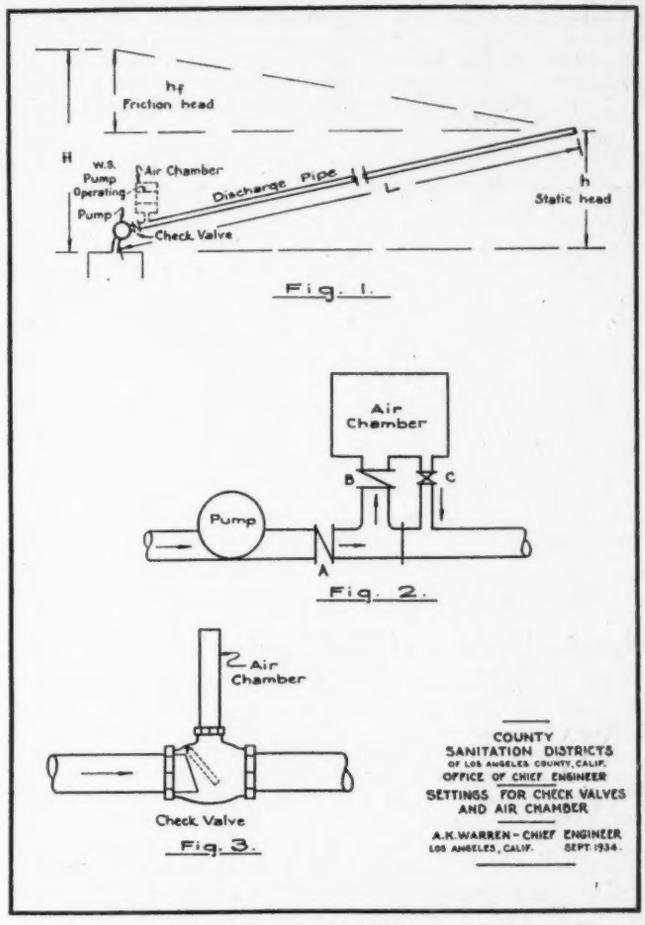
Rapid vs. Slow Closing Checks

It is obvious that what is desired is *a valve that will close rapidly.* One way to accomplish this is to have the valve seat inclined to shorten the distance the flap must move, and another is to use a valve with an extended hinge pin and arm so that the flap can be weighted. This weight prevents the flap from opening fully, causing a small increase in pressure, but accelerates its return movement when the pump stops. On one test in which a four-inch pump was forcing water into a pneumatic tank under 65 pounds pressure, the slam was eliminated by hanging enough weight on the check hinge pin arm to increase the pumping pressure less than one-half pound. This represented one of the most difficult situations for slam elimination because the pump line was short and there was little mass to the flowing water; thus in one controlling formula $a = \frac{F}{M}$, (a) was relatively large; and in the other formula $t = \frac{v}{a}$, (t) was relatively small.

Where it is not practicable to close the check valve in less than time (t), the use of *a slow closing valve* should be considered, but such valves are expensive and must be so designed that the final closure is made very slowly. An air chamber will provide a cushion in case the valve does not close before the flowing water comes to rest and will protect the pipe against excessive pressure. Immediately after the pump stops, the value of the shock absorbing compressed air in such chamber is its cushioning effect, which tends to maintain the gage pressure on the line instead of allowing it to drop to zero. It will thus delay the stopping of the water in the main pipe but the pressure being maintained close to the pump, where the air chamber will normally be placed, produces excessive acceleration in the short length of pipe between the chamber and pump and although the valve will slam violently, the pressure on this section of the pipe will not be excessive. After the valve has slammed the water in the main pipe will slowly come to rest, and then back into the air chamber, the gage showing an oscillation about the static elevation, as a center, with maximum and minimum at approximately $(h + H_f)$ and $(h - H_f)$.

The air cushion in Fig. 1 has purposely been drawn much larger than is recommended in order to illustrate the conditions. If, instead, it consists of a piece of pipe of the same diameter as the discharge pipe and about two or three diameters in height it will not supply enough water to permit any to flow backward through the check valve, thus avoiding a slam and at the same time preventing excessive pipe pressure. A surge will be set up with a maximum pressure of $(H = 2h)$ and minimum $(H = o)$.

(*Continued on next page*)



Arrangements of Air Chamber Installation to Eliminate Check Valve Slam and Water Hammer

*Chief Draftsman, Los Angeles County Sanitation Districts.

A Successful Arrangement

An air chamber arrangement which has been found to work very successfully is shown in Fig. 2. "A" is the main line check valve, "B" a check valve into the air chamber which should be nearly as large as "A" and set to allow water to enter the chamber. "C" is a gate valve or a plug cock smaller than "B". "C" must be opened or closed by trial until it limits the flow of water from the air chamber enough to prevent slamming of valve "A," and thereafter left in that position. The limited supply to the pipe damps out the surge, yet check valve "B" is large enough to admit a full stream to the air chamber and thus prevent excess pressure on the return flow.

To correct slam in an existing check valve, an air chamber can be built into the cover plate of the valve (Fig. 3). Care must be taken to so adjust the size of such a chamber that sufficient water is returned to close the flap by the time the water comes to rest but not sufficient to produce a slam.

This investigation was made about five years ago by the writer for the Los Angeles County Sanitation Districts and the data obtained applied to the correction of a number of troublesome conditions where valve slam was a problem.

The writer is indebted to E. A. Rutledge of the Rensselaer Valve Company for testing the formulae on many successful water works installations. A. K. Warren is Chief Engineer and General Manager of the Sanitation Districts and A. M. Rawn is Assistant Chief Engineer.

CHECKING WATER HAMMER*

When the water flowing through a pipe is stopped very suddenly there is rise in pressure in the pipe line that may at times amount, roughly, to 50 times the velocity in feet per second at which the water is moving at the instant.

The best cure for water hammer is a slow-closing valve. The next best cure is to provide an air chamber located as close as possible to the valve. If kept fully charged, an air chamber is considered to be of sufficient size when its capacity is one per cent of the pipe line it serve to cushion. Means of renewing the air cushion must be provided for.

Required Volume of Air Chamber

The size, that is, the volume, of an air chamber depends upon a number of factors of which the principal ones are:

The length and size of pipe that the air chamber serves.

The rate of flow of water through this pipe.

The pressure in the air chamber immediately preceding the stopping of the flow, and the pressure due to the stopping of the flow, and,

The nature of the action that puts the air chamber into service—whether it be instantaneous, or rapid, or prolonged.

The following treatment is based upon the first three factors. With reference to the fourth factor—it is the more or less instantaneous stopping of the flow that makes necessary the use of an air chamber. Hence, we are virtually assuming the condition of rapid closing. By this method a volume of air chamber is determined such that the energy of the moving water is absorbed between prescribed limits of pressure in the air chamber.

We have the expression,

$V = L \times P \times R^2$, in which

V is the internal volume of the air chamber in cubic inches,

L is the value from Table 59 for the size and length of pipe that the air chamber serves,

P is the value from Table 60 for the flowing pressure and the assumed maximum pressure, both in the air chamber, and

R^2 is the square of the rate of flow through the pipe in gallons per minute immediately before the stopping of flow.

Note—The flowing pressure can be determined approximately by deducting from the static pressure at the air chamber the loss of pressure in the run of piping (for which the size of an air chamber is being found) under the assumed rate of flow.

Determine the size of an air chamber for a ¾-inch branch, 20 feet long, carrying 10 gallons per minute, based on pressures of 20 pounds per square inch flowing, and 60 pounds per square inch maximum.

Substituting,

$V = 0.042 \times 1.6 \times 10^2 = 6.7$ cubic inches.

Having determined the volume of the air chamber, it becomes necessary to fix the proportions—whether to make it of relatively small diameter and correspondingly long, or short and "dumpy." If made of ¾-inch pipe, length would be 6.7/0.53, or 12.6 inches. Sectional area of ¾-inch pipe is 0.53 square inch from Table 61.

*From "Water Supply in Buildings," by Alex. W. Moseley, Mass. Inst. of Technology, 1935.

TABLE 59
Values of L

Length of Run, Feet	Size of Pipe, Iron Pipe Size ½	¾	1	1¼	1½	2	2½	3	4
10.....	.037	.021	.013	.0074	.0055	.0033	.0023	.0015	.0009
20.....	.074	.042	.026	.015	.011	.0066	.0045	.0030	.0017
30.....	.111	.063	.039	.022	.016	.010	.0068	.0045	.0026
40.....	.148	.084	.052	.030	.022	.013	.0091	.0060	.0035
50.....	.185	.105	.065	.037	.027	.017	.011	.0075	.0044
60.....	.222	.126	.078	.044	.033	.020	.014	.0090	.0052
80.....	.296	.168	.104	.059	.044	.026	.018	.012	.0070
100.....	.370	.210	.130	.074	.055	.033	.023	.015	.0087
125.....	.462	.262	.162	.093	.068	.041	.028	.019	.011
150.....	.555	.315	.195	.111	.082	.050	.034	.023	.013
200.....	.740	.420	.260	.148	.109	.066	.045	.030	.017
250.....	.924	.524	.324	.185	.136	.082	.057	.037	.023

Note that for each size of pipe value of L is proportional to length of run.

TABLE 60
Values of P

Maximum Pressure, Lb. Sq. In.	Flowing Pressure, Lb. Sq. In. 15	20	25	30	35	40	50	60	80	100
20..	42.									
25..	12.	56.								
30..	6.0	16.	72.							
35..	3.8	7.8	20.	90.						
40..	2.6	4.8	9.8	25.	110.					
50..	1.6	2.5	4.2	7.3	14.	36.				
60..	1.1	1.6	2.5	3.8	6.0	10.	49.			
80..	0.67	0.92	1.3	1.7	2.4	3.3	6.9	18.		
100..	0.48	0.63	0.82	1.1	1.4	1.8	3.0	5.4	27.	
120..	0.37	0.47	0.60	0.75	0.93	1.2	1.8	2.8	8.0	39.

TABLE 61
Sectional Area of Pipe

Size of Pipe Iron Pipe Size	Area of Internal Cross-Section of Pipe Sq. In.
½	0.30
¾	0.53
1	0.86
1¼	1.50
1½	2.04
2	3.36
2½	4.78
3	7.39
4	12.7

(The above article should be useful in meter shop practice and otherwise, where quick closing valves must be employed.—*Ed.*)

See also Magazine Section
Article by W. Ryon—on Surge Control

PRACTICAL ELECTRICITY IN THE PLANT

The A. B. C.'s of Electricity for the Water and Sewage Works Man

By MARSDEN C. SMITH

Engineer and Supt. Water and Electricity, Department Public Utilities, Richmond, Va.

Taken from a series of short articles by Mr. Smith, dealing with the A.B.C.'s of practical electricity for water works and sewage plant operators.*

The author, a graduate electrical engineer, is a well known water works operator. He is, thereby, peculiarly well qualified to present these discussions, which should be of considerable benefit to operators and designers less thoroughly grounded in electrical matters.

If there are points in his contributions not clear to the reader, Mr. Smith offers to answer inquiries.

THE increasing use of electricity in water and sewage treatment plants produces problems of design, operation and maintenance with which the engineer in charge is generally but little familiar. Fortunately, while advanced electrical engineering is a very involved subject, a helpful and useful knowledge of its fundamental principles can be obtained quite readily by the trained personnel of such plant. To that limited end the presentation of this series of articles* is confined.

The Author

PART I—ELECTRICAL UNITS

The Volt

One of the most important units of electricity is the Volt. It is the unit of electrical *pressure*. Just as we measure water force or pressure in units of pounds per square inch or feet of head, the unit of electromotive (electric moving) force is the volt. In equations, its symbol is E. Voltage is sometimes expressed in print as the emf—abbreviation for electric-motive force.

Standard voltages are 110, 220, 440, 2,200, 4,000, and 13,200. The individual for whom these articles are intended is rarely concerned with voltages in excess of 2,200. Furthermore, the 110 volt standard is now in the process of change, and seems to be quite generally replaced by a standard of 120 volts.

Extra-heavy fittings and greater precautions are necessary with greater water pressures; so too, must greater care be taken both of life and property when higher electrical pressures are used. However, pressures of as little as 110 volts, in common domestic use, may prove fatal and care should always be taken to avoid personal contact with even these relatively low pressure circuits.

Most electrical apparatus is designed to operate at one of the above mentioned standard voltages. The use of other than these standards is both unnecessary and uneconomical. Incandescent lamps are generally rated at from 110 to 125 volts in five-volt increments. They may be obtained designed for 220 volts, but such lamps are not recommended except where no 110-volt service is available. Even then safety and economy demand the use of 110-volt lamps if possible.

Some Practical Considerations

Lamps are very sensitive to voltage change; and the operator should see that the lamps are purchased for the circuits on which they are to be used. For example, if the average voltage at the station is known to be 118 volts, 120-volt lamps should be used. Here the use of 110-volt lamps would increase the lamp replacement cost by almost 300 per cent.

Motors are not nearly so sensitive to voltage change as are lamps and will operate successfully at applied voltages within 10 per cent above or below normal rated voltage. Greater voltage variation will generally cause excessive heating and unsuccessful operation.

Small motors (less than 5 horse-power) are usually single phase and operate at standard lamp voltages. Large motors, 5 to 50 H.P., are cheaper when designed for 220 or 440 volts. Larger than 50 H.P. should be designed for 2,200 volts. Of course, local conditions may change these recommendations. One large plant has motors from 3 to 300 H.P. The station designers used 2,200 to 440-volt transformers; motors between 50 to 300 H.P. were ordered for 440 volts. A second set of transformers reduced the 440 volts to 220 volts for the smaller motors (up to 50 H.P.). Certainly this is unfortunate, because the larger and more expensive motors would have been of less first cost if designed for 2,200 volts, and the 2 to 5 per cent transformer losses, which materially increases operating costs, would have been saved. The smaller motors could all have been 440-volt type, thus here again would have been saved the second transformer losses. Here we see an evident error that a better understanding of the problem of electricity in design would have avoided.

Other than electrical engineers often fear the use of 2,200 volts. It is true, that there is no need for this higher potential, unless the size and number of motors justifies its use. However, where the total of as much as two or three hundred horse-power is required for motors larger than 50 H.P., the higher potentials are certainly advisable.

The relative advantage of the use of 220 or 440 volts as the operating voltage for the smaller motors is not so definite. However, for larger plants 440 volts seems more desirable. Safety requires the same care with 220 volts as with 440 volts, and a much wider range of motor sizes can be more economically operated at this than at 220 volts.

The Ampere

The second important unit of electricity to be considered is the Ampere.

It is the unit of electrical *rate of flow*. We are familiar with the various measures of the rate of flow of liquids; gallons per minute, etc.; so we should think of the unit rate of flow of electricity as the ampere. In equations its symbol is generally (I). In print Amperes are sometimes abbreviated to "Amp." Larger pipes are required to carry larger rates of flow of water economically; so too, larger wires are needed to carry larger currents (amperes) economically. Small pipes may be uneconomical because friction causes too great loss of water pressure. In exactly the same way, wires may be too small for the amperage (current flow) and cause an uneconomical loss of electrical pressure (voltage drop).

There are no standard currents as in the case for the voltage rating of electrical apparatus. Each appliance, lamps, heating devices, etc., takes from the circuit a current dependent upon its design and lack of resistance to flow. Motors require, for example, a current that varies with the load. All electrical apparatus (except lamps) should have its normal current rating stamped upon its nameplate. Lamp current is determined by dividing its watt rating by its rated voltage.

However, there are certain appliances such as wire, fuses and switches that are rated in terms of the current they may safely carry; thus currents are to this extent standardized. The plant manager should realize that these current ratings are fixed by the National Electric Code, and he should not permit greater current to flow through accessories than the limits established by this code. Oftentimes circuits are fused far beyond the rated capacity of the wire, which is supposedly being protected by the fuse. Such practice is both uneconomical and dangerous.

Most appliances, including motors, are connected between the supply lines, that is, in parallel. In this way the circuit voltage is impressed upon each appliance, causing a current to flow through the appliance of a quantity dependent upon its rating and load. These increments of current are added, hence the supply wires carry greater and greater total current as we work back toward the source of power. For example: Five 1,000-watt

*From WATER WORKS AND SEWERAGE, issues of October and December, 1936; February and April, 1937.

lamps rated 100 volts each require 10 amperes. Let us designate these as numbers one to five, from that nearest the supply to the most remote. Both wires between the supply and the first (No. 1) lamp carry 50 amperes; between 1 and 2, 40 amperes, and so on until between 4 and 5 the current has reduced to 10 amperes, or that required by No. 5—the last lamp. They all have (practically) the same voltages as the supply applied to their terminals.

Some Practical Considerations

When installing new apparatus there are two considerations of great importance: (1) Use wire of ample conductor size. (2) Employ insulation having a large factor of safety. For low potential circuits (less than 600 volts) 30 per cent pure rubber insulation will generally prove more economical than the standard code insulation. Particularly is this true in water and sewage treatment plants due to the prevalence of dampness in such locations. For 2,200-volt circuits rubber insulated cable is more easily installed than is varnished cambric cables. Rubber depreciates must more rapidly when subjected to heat and grease or oil than does varnished cambric, but it is less affected by moisture. For this reason, varnished cambric is never used without some form of outer coating, usually lead. Modern synthetic resins and other compounds are rapidly proving their value for use as the outer protective coating, materially lessening the installation difficulties. These coatings are deserving of consideration.

In general, where expert electrical maintenance is not available, the proper thickness of 30 per cent pure-rubber insulation, on conductors of adequate size for the current they will ever have to carry, will certainly well repay the increased investment cost. Where such expert maintenance is available, varnished cambric insulation may prove better for 2,200-volt circuits.

The Ohm

The unit of electrical resistance is the Ohm. In equations its symbol is (R).

If we close the spigot, even though there be water pressure at the valve, no water can flow because the resistance is too great. The same result is obtained when opening an electric switch; the pressure (voltage) still exists but the resistance (ohms) become so great that no current (amperes) can flow. This is an example of localized resistance.

Electrical resistance may be distributed, in fact *is* distributed along the conductor just as is the pipe resistance to water flow proportional to its size, length and condition. Fortunately, in electrical circuits the loss of voltage (pressure) is always directly proportional to the resistance and rate of current flow. Therefore, the loss of power (to be discussed in the next article) is proportional to the resistance and the square of the rate of flow or current.

An electrical device, such as a lamp, does not use or destroy current in the sense that an oil lamp consumes oil, but by its relatively high resistance limits the current that may flow as a result of the impressed electromotive force—voltage. Thus we have the simple but important equation known as Ohm's Law:

$$E = RI \quad \ldots\ldots (1)$$

There are no standards of resistance; however, the established resistance per unit length of electrical conductors and resistance alloys may be found in any electrical engineer's handbook.

Direct vs. Alternating Current

Formula (1) applies to circuits that contain resistance only, or in which the frequency is zero, as in the case of direct current. This term frequency must now be understood. If the polarity between two wires (A and B) of a circuit is not changed, the current flow will always be in one direction in the wires, thus constituting what is termed direct-current—(D.C.). If we alternate wires A and B from one side of the source to the other, once each ½ second, the direction of current flow in A and B will reverse once every ½ second, and will begin to flow in the original or *same* direction in a given conductor once every second. Electrically we would say that there was being produced "An electromotive force (current) having a frequency of one cycle per second." Fundamentally that is the difference between alternating and direct currents. Modern alternating currents closely follow the sine law in their time-potential value; and the standard frequency in this country is now sixty cycles per second.

When direct current is applied to a coil of copper or other wire (having resistance R) wound around iron, if the current and voltage be carefully measured, equation 1 will be found to apply. When an alternating voltage is applied this equation no longer can be used. This is because any magnetic circuit is an inductive circuit, and the effect of an inductance is to divide the alternating current into two components which are at right angles to one another. Hence to obtain the same current through the coil when an alternating voltage is applied, a greater voltage is required than when a direct voltage is used. So for alternating current circuits equation 1 becomes:

$$E = ZI \quad \ldots\ldots (2)$$

in which Z is the impedance of the circuit.

Many devices, such as heating appliances and lamps have little or no inductance; hence may be used on either direct or alternating current circuits of the rated voltage; but inductive devices, such as transformers and motors, cannot be used on direct current circuits unless especially designed for the purpose.

Transformers

The engineer for whom these articles are intended rarely is concerned with the use of transformers; however, a brief discussion of them is advisable. The standard transformer consists of two stationary coils of wire insulated from one another and wound around a common iron core. A special class, the auto-transformer, commonly used for motor starters, has only one winding with connections to some desired turn between the two end turns.

Of the winding in the auto-transformers, the turns connected to the power supply is the primary; the secondary winding is connected to the load. The voltage change between the primary and secondary is in direct ratio to the number of turns used in the two windings; conversely, the current is in the inverse ratio to the number of turns. Hence a transformer may be used to increase voltage as readily as to reduce it—the so-called "step-down." Many deaths have resulted from opening the high voltage switch, assuming the transformer "dead," when in fact the 110-volt side was still energized thus producing normal high voltage in the primary.

Instrument transformers are especially designed to accurately reduce the potential or current, as the case may be, for metering and other purposes. Care should be taken to always connect the secondary terminals of current transformers together with wire (short-circuit them) if the secondary circuit must be disconnected for any purpose while the primary continues to carry current.

It is well to know that transformers, if kept cool enough, can safely carry much greater than rated loads. Cold winter weather and artificial ventilation around the tanks is effective, but hot locations and days are dangerous. Tank temperatures should never exceed 90 degrees C. Contamination of the oil by dirt or even traces of moisture must be avoided. In larger units the oil should be examined monthly by a competent inspector.

The Watt

Another very important unit of electricity is the Watt, which is the unit of electrical power. The more commonly used unit is the Kilowatt, which is one thousand watts. The symbol for the Watt is (W); for the Kilowatt (KW). The mechanical unit of power is horse-power; one horse-power (H.P.) is the equivalent of 746 watts or 0.746 kilowatts. Due to the fact that the efficiency of small motors is approximately 75 per cent, the input in kilowatts is, by coincidence, closely the same as the mechanical output in horse-power.

With direct current, electrical power is the product of the current (I) and the voltage (E). Thus we have:

$$P = EI \quad \ldots\ldots (3)$$

However, substituting for (E) from equation (1), wherein E = RI, we have:

$$P = RI^2 \quad \ldots\ldots (4)$$

Or similarly, substituting for (I) where $I = \frac{E}{R}$ in the same equation:

$$P = \frac{E^2}{R} \quad \ldots\ldots (5)$$

Now, it becomes evident that electrical power varies directly with both current and voltage, if resistance is not considered, but as the square of either (E or I) if the resistance is considered.

PART 2

POWER FACTOR; ITS SIGNIFICANCE

With alternating currents equation (3) becomes the more familiar form, and—

$$P = EI \cos \theta \quad \ldots\ldots (6)$$

In this equation the Cos θ is designated as the power-factor. If an alternating current circuit contains resistance only (no capacity or inductance) the angle θ becomes zero; hence, its

cosine, which is the power-factor becomes unity. Electrical installations in water and sewage treatment plants rarely contain sufficient capacity (condenser action) to be of any practical effect, hence we may omit further reference to "capacity" in these articles. Inductance, however, is of great importance, and in practical installations may reduce the power factor as much as 30 per cent.

The actual mathematical value of the power-factor of practical circuits is difficult to compute; however, it is well for the engineer to have some idea as to the values that may be expected. Incandescent lamps and heating devices, since they contain but little inductance, are virtually non-inductive; hence, their power-factor closely approaches unity. Motors and transformers vary through very wide limits. Of course, a transformer being highly inductive when delivering no load, its power-factor is quite near zero; but, at rated load the power-factor becomes quite nearly that of the circuit being supplied by the transformer. Small motors, up to 5 h.p., require power at not more than 60 per cent power-factor; particularly so when operating at light loads. Large induction motors, at full load, now may operate at as high as 94 per cent; and, synchronous motors, more fully discussed in coming articles, may be operated almost as desired.

The objection to low power-factors is that larger currents are required for the same power, thus increasing power losses in the whole electrical system. Furthermore, low power-factors cause much wider voltage variations than do greater loads with higher power-factors. For this reason many power companies offer reduced rates to those consumers whose apparatus constitutes a load having a favorable power-factor. This fact may be of value to many larger operators. It is true, however, that plant operators can exercise but limited control over the power-factor of their stations except through the selection and operation of the motors. This phase of the subject will be later discussed when motors and their characteristics are considered.

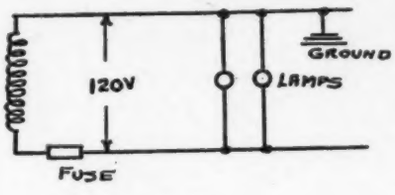


FIG 1

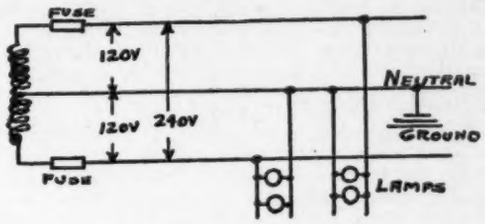


FIG 2

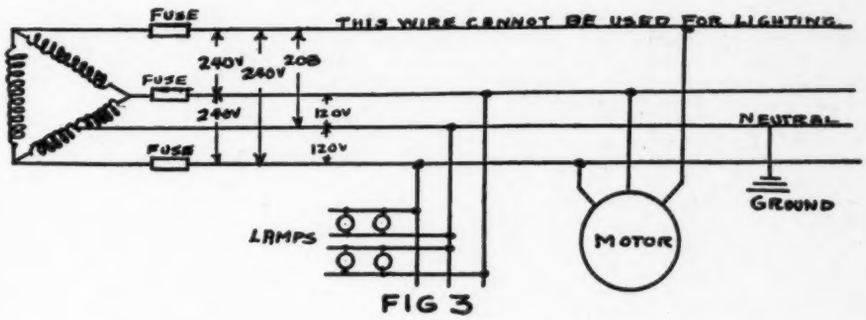


FIG 3

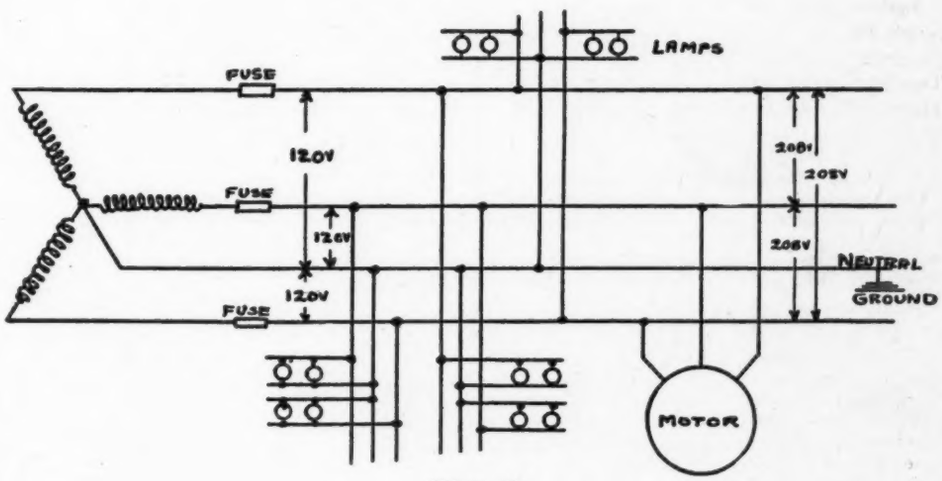


FIG 4

Circuits: Figs. 1, 2, 3 and 4

The Kilowatt-Hour

The kilowatt-hour (KwHr) is the unit by which electric power is generally sold. As its name implies, it is the average power consumed, in kilowatts, multiplied by the number of hours involved. For example: if an electric iron is operated for two hours at average rating of 600 watts, there is used $600 \times 2 = 1200$ watt-hours, or 1.2 KwHrs.

The volt-ampere (VA) is the product of the volts and amperes of a circuit or an appliance, without reference to power. Thus, the transformer is always rated in kilo-volt-amperes (KVA) because its parts can be designed for the voltage and current value desired, but the power-factor of its load may vary through wide limits. Thus we see that:

$$KW = KVA \times \text{Cos } \theta \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Hence, if we are to know the safe load for a transformer rated at 100 KVA, we must first determine the power-factor of the load to be connected. If we may assume the load to be one-half lamps and one-half small motors; we may approximate the average power-factor to be 82 per cent. Hence, by equation (7) we find Kw = 100 × 0.82 (82 Kw) to be the safe load for this case.

The Cos θ, which we now recognize to be the power-factor, is actually the cosine of the angle of time-phase displacement between the current and the voltage of an alternating current circuit containing "capacity" or inductance.

Circuits

The term, "phase," is also applied to designate the circuits of an alternating current system. In the "Single-Phase" system the *voltages* are in the same time-phase in all parts of the system. In the "Two-Phase" system, the two voltages are 90 degrees apart. In the "Three-Phase" system they are 120 degrees apart.

In another sense, there are in effect one or two or three circuits in the single, the two or the three-phase systems. Of course, the power-factor may be different in each phase; hence the currents in the phases may not be of exactly the same angular difference as the voltages producing these currents.

The simplest circuit is that comprising the single-phase (two-wire) system, as in Fig. 1. This is used for the final branch circuit of larger systems, and in case of small loads, including most residences, it is always used.

The single-phase, three-wire system is next in capacity and in frequency of use. Single-phase, two-wire branches are connected thereto as shown in Fig. 2. The evident advantage of three wires over the two-wire system is that when loads are

balanced, the neutral carries no return current, hence the lamps and appliances operate at 120 volts, whereas the circuit operates at 240 volts. In this way twice as much power can be carried over the same wires, by merely adding one additional wire.

Grounding Practice

The neutral must be grounded. It should be the same size as the phase wires; and, it must *not* be fused or connected to any switch, and the wire used for the neutral must have white covering for identification, and the neutral must be connected to the white screw in all receptacles. In the single-phase, two-wire system one of the wires must be grounded and the same rules as given for the neutral conductor wire must be observed.

(Grounding practice as it affects water works piping will be given some discussion at a later point in this article.)

Three-Phase Standard for Heavy Duty

The three-phase (three-wire) system is standard for motor loads. If lighting is required, the neutral of one transformer (made larger to carry the additional load) is brought out as in Fig. 3. Most power companies limit the single-phase load that may thus be supplied to 50 KVA. In addition, this method of supplying the lighting loads makes service interruptions more frequent because of the necessity for grounding one of the transformer windings. Perhaps most serious of all is the objectionable flicker in the lights obtained when starting motors, particularly elevators connected to the system. Of course, economy often rules and hence this system is frequently used; but unless the motors are relatively small, and are started very infrequently; it is undoubtedly better to separate the lighting and very small motors from the power system.

The formula for power in the different systems, with balanced load, is given in the following table:

System	*Power*		*Max. Volts to Ground*
Single-Phase (Two-Wire)	$P = EI\cos\theta$	Here E=120	120
Single-Phase (Three-Wire)	$P = EI\cos\theta$	Here E=240	120
Two-Phase (Four-Wire)	$P = 2EI\cos\theta$	Here E=120	120
Three-Phase (Delta)	$P = \sqrt{3}EI\cos\theta$	Here E=240	207.8*
Three-Phase (Y)	$P = \sqrt{3}EI\cos\theta$	Here E=207.8	120

*Volts to ground on lighting circuits is 120.

The two-phase (four-wire) system is so little used that no discussion is necessary.

PART 3—CIRCUIT PROTECTION

Fuses and all electrical circuit-breakers are similar in function to the safety valve on a boiler; and hence they should be seriously considered. They are all intended to open the circuit, thus stopping the flow of current, should the current exceed a predetermined or dangerous rate through these safety devices.

While the problem of circuit protection becomes at times quite involved, still there is much that can here be discussed to advantage. In the first place, the Natinal Electric Code is now almost universally accepted as the authority for the safe utilization of electricity in all except central station systems. Consequently, the engineer should obtain a copy of this useful and important publication.

Fuses and Circuit Breakers

Fuses are the cheapest and simplest of all protective devices. They consist of a piece of relatively high resistance alloy wire or tape, designed to melt, and thereby part, at the current at which the fuse is rated. The wire is enclosed in a suitable flameproof case to prevent ignition of surrounding materials at the time the fuse flashes and melts. The use of fuses is now confined almost entirely to circuits the importance of which does not justify the more expensive and accurate devices. The type now approved, known as the "refillable type," permits the renewal of the fuse link, using the expensive part (the cartridge) over and over again.

For those applications in which the replacement of fuses is frequently necessary, thermal relays or air circuit breakers are to be recommended. Motor circuits fall in this classification. Thermal relays and circuit breakers can permit a greater than rated current pass for a short time, as during the starting period of a motor, and therefore are of especial advantage for this service. The current capacity as well as the voltage ratings of this class of protective devices are limited, and when greater limits are needed the oil circuit breaker must be used.

The oil used in circuit breakers must be especially selected for this service; and no other oil should ever be used. This precaution is essential for the reason that the oil must have high insulation value, high flash point, low carbon content, and wide temperature viscosity constant—all in order to quickly quench the arc that is formed with each opening of the contacts.

Relays

The overload operation of an oil circuit breaker is usually actuated by an auxiliary device known as a relay. Relays may be of several types: the instantaneous, the inverse time limit, and others. The modern relays are truly marvelous devices; however, the types needed by the water works plants are, in the main:

(1) *The Instantaneous Type*—dash-potted relays with direct mechanical trip. Here a coil which carries all or a definite part of the load current raises a solenoid when the current flow exceeds a predetermined value. The rising solenoid mechanically releases a trigger, which in turn permits the oil circuit breaker to open. An oil-filled dash-pot retards the solenoid movement. The dash-pot opening is adjustable, hence the time for opening with a given over-current can be selected as desired. The oil in the dash-pot should be inspected at intervals and replaced if dirt or sludge has accumulated. While rather crude, this device is sufficiently accurate for the protection of most small motor circuits.

(2) *The Air Bellows Type*—This type is not much used now. An air bellows, with an adjustable escape valve, is substituted for the oil dash-pot described above.

(3) *The Induction Type*—This relay is more expensive than those above mentioned, but its use is justified in the protection of all important cicuits.

With the induction relay, when the current exceeds the desired value, the torque on an aluminum disc, mounted on the same shaft with the relay contacts, causing the shaft to rotate. Such rotation causes the opening (some cases the closing) of the relay contacts, which in turn electrically energize the main tripping coil on the circuit breaker. The advantage of this type is that the time of opening the main circuit breaker can be determined to a fraction of a second; also, that the limits of control are so wide that these relays, with suitable current transformers, become almost universally applicable and highly accurate protective devices.

To repeat, too much care cannot be given the subject of circuit protection. Over-fusing (use of fuses with too great capacity) of circuits is dangerous and uneconomical. Noting a too frequent operation of the overload, protection of any appliance warrants prompt investigation. The source of the trouble should be remedied by correction, rather than following the easiest path of using too large circuit protection to overcome an annoying operating circumstance.

Grounding—Its Essentiality

It is no exaggeration to say that without adequate grounding, satisfactory electrical service would be virtually unknown. In addition, safety would be a word more than a reality. Even so, many groundings are so deficient in quality as to become actually a hazard instead of a safety effect. Many persons have been swindled into paying for a false sense of security when installing lightning rods having many ornamental glass balls but no grounds. Thereby the victim is actually inviting the lightning to strike the house but offering no protection by way of a cable or rod to conduct the electric discharge into the earth and there dissipate it.

Grounds should be carefully made. Use not less than No. 2 B&S gauge copper wire. Several grounds are preferable to a single ground in order to lessen the chances of broken connections. Use the water pipe system; the larger the pipe, the better. Do not use the gas, gasoline or oil pipe lines. Be sure the connection between the wire and pipe is electrically and mechanically as perfect as possible. If no pipe system is available, drive at least three 1¼-inch pipe, or equivalent copper rods, *well below the moisture line* in the earth. A good test is that the driven ground connection, when shorted, should blow a 30-ampere fuse at 120 volts.

Much discussion has recently been raised in the water works field as to the effects of attaching the electric circuit "neutral" wires to the water pipes. There is no question that the damage done to water systems by stray direct currents, as from street railways, has been indeed enormous. Here we have electrolysis at its worst, and the destruction of the metallic pipes at spots where the current leaves the pipes is rapid. This condition is inexcusable and should be prohibited everywhere.

However, in the alternating current system the damage is not so evident, and many doubt its *real* existence—or at least its seriousness. Also it is quite possible that were all connections between electrical and water systems removed, electrical service as we know it today would be a thing of the past. And even should such action force the electric companies to seek other means of obtaining the necessary protection now provided by these ground-

ing attachments, the water systems would be subject to the same distress now *debatedly* suffered. It would seem certain that more severe difficulties would be caused by the same currents finding their way to the water system in a then uncontrolled routing and dissipation which present practices have been designed to effect.

The necessity for grounding the electric circuits is to prevent dangerous high-potential voltages (through mistakes or accidental contact) from increasing the normally low-potential circuits to a dangerous loading. The wiring for lighting systems of buildings is designed for a maximum of 150 volts to ground. Let us assume that a street series circuit operating at 5,000 volts should fall across the service wires from the pole to your home. With no ground on the "neutral" of your secondary wiring, its potential would be raised from its normal low value to a maximum of 5,000 volts. Certainly something must happen; either a fire is started, or perhaps a member of your family may be killed. The effect of such danger has been observed when service thawing current reaches the house wiring. In these instances the "ground" has worked in reverse, but proves its safety value and the necessity of "breaking" the service line before electrical thawing is started. Now consider these same conditions to exist, except that now your "neutral" is properly grounded. When the high-potential circuit is now temporarily crossed with service, the high-potential currents are safely carried to ground, and no one in the home would realize the possible disaster that the ground connections have avoided.

When, What and Why Ground?

There is no doubt that a full study and discussion of the entire subject of grounding by the new functioning joint committee will prove well worth while. It is certainly to be hoped that there will result a greater care in the preparation and arrangement of ground connections between the electric and water systems, and that the volume of curent flow be intelligently regulated. We, the water utility interests, should not embarrass this effort by hasty demands to prohibit all grounding of water systems. As a matter of fact, we could not do so, even if thoughtless enough to demand such.

[Water works men have themselves found difficulty in effectively grounding pumping station motor circuits by any other method than an efficient connection to their own pressure mains leaving the station.—Ed.]

No wires used in lighting systems should have more than 150 volts to ground. The wires of power circuits, such as 220 or 440 volts, *should not be grounded.* All appliances, frames of motors, conduit, etc., in addition to the "neutrals" of lighting systems, should be carefully and effectively grounded. Inspect grounds frequently. The snuffing out of a life may be the penalty if you do not. Satisfactory operation is another, if secondary, reason for so doing.

PART 4—MOTORS

Alternating current motors are of two general types: the synchronous and induction. The main difference between these two types is that, while the synchronous motor can run only at a definite constant speed (synchronous speed), the induction motor must operate at a speed dependent upon the load applied, but never at synchronous speed. There are other important differences that, to better advantage, will be mentioned later.

Synchronous Type

At a given frequency the speed of a synchronous motor may be determined by the equation;

$$N = \frac{120f}{P} \quad \ldots\ldots\ldots (8)$$

in which N = revolutions of rotor per minute (RPM); f = frequency in cycles per second; P = number of poles.

Since the standard frequency is 60 cycles per second, equation 8 is generally expressed in the form:

$$N = \frac{7200}{P} \quad \ldots\ldots\ldots (9)$$

From this it is evident that the maximum speed for a 60 cycle motor is 7200/2 or 3600 RPM, and the speed, N, from equations 8 or 9 is known as the synchronous speed of the motor. This, for 60 cycle motors, is the constant 7200 divided by the number of poles; and, since the number of poles must be an even number, synchronous speeds become 3600, 1800, 1200, 900....RPM. One of the greatest limitations of the synchronous motor is that it cannot be built to operate at other than synchronous speeds, when oftentimes an intermediate speed is needed.

On the other hand, the fact that it runs at an exact speed is quite frequently its greatest asset. Electric clocks and timing devices depend upon this characteristic for their value and dependability as to accuracy. Pump drives, and mechanical devices of all types that require an exact and fixed speed, necessitate the use of the synchronous motor for this reason.

Another marked difference between the synchronous and induction motor is that the former requires salient magnetic poles, excited (magnetized) from a source of direct current; whereas, the induction motor has no such poles and requires no separate excitation. In fact, the standard squirrel-cage motor is well named, because its rotor is essentially nothing more than a circle of bars parallel to the shaft which are held in place and short-circuited by two metallic rings. Picture the revolving cage for the squirrel's exercise and you have it—thus, the name.

Unfavorable Characteristics

The necessity for this auxiliary direct current is indeed unfortunate, because direct current generators are difficult to maintain. Hence, greater skill and maintenance are required for synchronous than for induction motor operation. Then, too, the starting characteristics of the synchronous motor are rarely satisfactory. The starting torque (that is, the twist or pull) cannot approach that of the induction motor; frequently necessitating expensive and complicated methods of holding the load off the motor until it has reached full speed. Fortunately, centrifugal pumps may frequently be started under no-load without inconvenience, which renders this deficiency of the synchronous motor of no real importance.

Favorable Characteristics

On the favorable side of the ledger, the synchronous motor does possess the ability to operate with a "leading" power factor, contrasted to the rather decidedly "lagging" power factor of the standard induction motor. As has been stated previously, many power companies offer a lower rate to consumers whose requirements make permissible a desirable power factor. Where this is the case, the ability of the synchronous motor to operate at the "leading" power factor may have influence in the selection of the type of motor to be adopted.

From the above, it can be seen why, for water works and sewage treatment plants, the use of synchronous motors is frequently advised against. They are only to be considered when exact speed is essential or power costs may be lowered appreciably by the favorable power factor. Even then, the engineer will do well to be certain that savings in power bills will offset the increased operating difficulties that are certain to be realized in the use of synchronous motors.

Induction Type

The induction motor differs from the synchronous type in that it requires no separate excitation, and its ability to operate at a variable speed, as contrasted to the constant speed synchronous motor.

At no load an induction motor will run almost up to its synchronous speed. It should be understood that while the induction motor has no salient poles, the stator is wound to produce two, four or any even number of poles, just as is the stator of a synchronous motor; hence it has a synchronous speed of 3600, 1800, 900 RPM, just as does the synchronous type.

As the load on an induction motor is increased, the speed gradually lessens until at full rated load the speed is reduced from two to four per cent of its synchronous speed. Thus a given motor may have a synchronous speed of 1200 RPM, a no load speed of 1199 RPM and a full load speed of only 1170 RPM. If the load is further increased, the "slip" (as the loss of speed is called) will increase until a definite value is reached, at which point the motor will come to a stop. This load is known as the "pull-out" load.

Favorable Characteristics

Standard induction motors have very favorable starting characteristics, requiring relatively a small starting current and producing 200 or more per cent of full load torque. They are the most rugged and reliable of all motors. But while they will successfully operate under most adverse conditions, reasonable care should be taken to keep the air ducts and windings free from lint and dirt. The oil in the bearings must be flushed and changed at least once each year.

Smaller and specially designed induction motors require no starting device, and may be started by applying normal full voltage. Larger motors require reduced voltage for starting, which is

usually obtained from auto-transformers, called starting compensators. Two coils, each on an iron core, are connected open-delta across the three-phase lines; a 40, 50 or 60 per cent tap is taken to the motors for starting. After the motor has started and reached a constant speed, the compensator is disconnected and full voltage goes to the motor.

Variable Speed Motors

The wound-rotor induction motor, for operating at variable speeds, is not so rugged as is the standard squirrel-cage type. It is more expensive and also usually less efficient. A misunderstanding of the speed characteristics of these motors has caused no end of trouble. We may gain a clear conception of the speed variation of the wound rotor, induction type motor if we think in terms of "slip." As stated above, the standard squirrel-cage motor "slip" varies from virtually nothing at no load to about 3 per cent at full load. With the wound rotor, external resistance may be added to the rotor circuit, the effort of which is to *increase* the slip. Hence, this motor will run at essentially *constant* speed at no load, regardless of the amount of external resistance introduced in the rotor circuit. But, as the load is applied, and the greater is the external resistance, the more rapidly will the speed drop off.

Practically, this means that if we desire to drive a centrifugal pump at a variable speed, in order to vary the head and quantity delivered, we must first learn from the pump manufacturer both the speed and the horse-power required by the pump for each value of head-quantity desired. This data is then furnished the manufacturer of the motor who will design the external rotor resistances so that the various controller positions will connect the correct resistance to cause the speed to be that needed for the pump to operate under the desired condition.

Since power is a product of speed and torque, it should be remembered that less horse-power output can be obtained from a motor operating at a reduced speed than at its normal full speed. The reduction in motor output is approximately proportional to the reduction in speed. This fact should be considered at the time of purchase in order to be certain that the motor will not be excessively heated when operating at any of the reduced speeds. The same resistors that serve for speed control are also used for starting, hence no compensator is required as is the case for some of the standard squirrel-cage types.

Motor Ratings

The rating of most electrical apparatus such as motors, transformers, etc., is based upon the temperature rise that will occur when the device is operated continuously under normal full load and normal voltage conditions. Many manufacturers recommend a limit of fifty-five degrees centigrade rise, while other base their estimates upon a rise of only forty degrees. After all, this simply means that with a given motor rated at 100 HP, at 40 degree rise would be rated at 125 HP at 55 degree rise. All things considered, it seems to be the consensus of opinion, and dictate of wisdom, that all important motors in water works and sewage treatment plants should be purchased for a guaranteed rise, not to exceed forty degrees centigrade.

RAPID EMERGENCY METHOD OF THAWING HYDRANTS*

By E. E. JACOBSON

Chief Engineer, Lexington Water Co., Lexington, Ky.

One of the many worries of the water works man during the cold winter months is the problem of fire hydrant maintenance and their operation when the thermometer drops below freezing.

Proper inspection and drainage of fire hydrants will eliminate most of the trouble but hydrants only a few days after inspection have been found to contain water in the barrel. As the weather turns cold the water in the barrel becomes ice and the hydrant will not operate. No doubt every water works superintendent in states that have cold winters has experienced frozen fire hydrants.

The method used in Lexington, Ky., for a number of years as an emergency method of thawing ice from hydrant barrels is by pouring concentrated sulphuric acid into the hydrant barrel. During the Fall each piece of apparatus of the Lexington Fire Department is supplied with a quart bottle of sulphuric acid (66% commercial). When the acid is used the Lexington Water Company is notified and another bottle is sent to the fire station. In the Spring of the year these bottles are collected and fresh acid is issued each Fall.

When answering an alarm and a hydrant is found to be frozen; the acid is poured into the barrel through the nozzle and a slight pressure put on the stem operating wrench. As soon as the heat produced by the acid drills a hole through the ice cake the hydrant is opened, flushing out the acid with the first gush of water.

In frozen hydrants we have found that the ice forms first above the valve and in most cases it is doubtful if the acid reaches the valve because the stem turns and the water is turned on as soon as the ice melts around the stem.

The average time for thawing hydrants with acid is about three minutes although this would depend upon the thickness of ice in the barrel of the hydrant, and might vary considerably from the above time if very thick.

The advantages from this method of thawing hydrants comprise the ease of handling the thawing material on the fire trucks, the small space necessary on the trucks, simple to use, inexpensive, and the rapidity of results. Hydrants in which acid was used have been taken apart and no ill effects to the hydrant parts could be found.

The effectiveness in the use of sulphuric acid for this purpose can be determined by the following letter from the Chief of the Lexington Fire Department:

Mr. E. E. Jacobson, Chief Engineer — April 11, 1936.
Lexington Water Company,
Lexington, Kentucky.

Dear Mr. Jacobson:

Relative to our conversation this morning, I am furnishing you with all the information that I have in regards to the use of sulphuric acid in thawing fire hydrants during extreme cold weather.

In case a hydrant is found to be frozen, one of the caps of the hydrant is removed and a quart of acid is dumped into the barrel of the hydrant. The suction hose is then replaced on the hydrant, and in the majority of the cases the hydrant is thawed out by the time the suction is replaced, and the hydrant is turned on. The water and acid is allowed to flush out through the pumper or the hose, and we have found that little or no damage is caused by this action, due to the fact that the acid is neutralized by water to such a degree that it is harmless to the pumper or the hose.

In some instances the acid is a little slow about thawing the hydrant, but in these cases it is usually in certain parts of the city, where the surface water seeps in the barrel of the hydrant, causing the hydrant to have more water than usual in the barrel, but as soon as these hydrants are found, your company has had them filled with alcohol, thereby eliminating this trouble.

You will notice that we say that we replace the suction or the hose to the hydrant before we turn on the water. This is done to prevent acid burns to members of the department and the hose and apparatus that is near the hydrant. The first spurt of acid and water from the hydrant would be dangerous to any thing that it touched, but by replacing the cap, the acid is diluted with the water to a point where it is practically harmless to any thing it might touch.

It has required from two to eight minutes to thaw a hydrant with acid, where it usually requires about ten minutes to thaw out a hydrant with a regular thawing device, old style thawing device.

A test was made at fire department headquarters today. A fifty pound block of ice was used and one quart of sulphuric acid was poured into a hole in the ice. Ten minutes later a hole was burned in the ice eight inches deep, six inches wide and ten inches long. Of course, this was a little longer than it would have been in a hydrant, due to the fact that acid will follow the stem of the hydrant and penetrate into the ice faster than it did during the test. We have found the use of sulphuric acid for thawing hydrants to be most satisfactory.

C. J. HENRY,
Chief, Lexington Fire Department.

*From WATER WORKS AND SEWERAGE, December, 1936.

THAWING FROZEN SERVICE PIPES

By REEVES J. NEWSOM*

Consulting Engr., New York, N. Y.

The most rapid and economical method of thawing has been by the use of electric current. The most commonly used scheme of electrical thawing has been to get the local power company to mount transformers on trucks and to connect to existing power lines in the streets. The cost of this method is apt to be greater than the use of other types of electrical equipment, but there is usually not time to get other equipment after the freeze-ups began. In outlying districts no power lines were available in some cases, and other methods had to be resorted to. Engine driven generator sets especially designed for the purpose were only occasionally available, but the modern electric welding outfit was found to have approximately the voltage and amperage range required for thawing services, and where these outfits were used for thawing mains two of them were generally used in parallel.

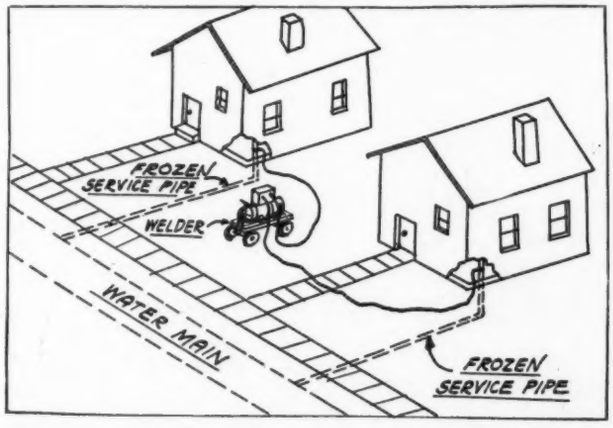
A third type of electrical equipment which was effective for short services, where connections could be made close together, was a small portable transformer with a capacity of about 150 amperes at 20 volts. On some systems a surprising number of services were successfully thawed with equipment of this type—the current being taken through the residence wiring outlets.

Where only a few frozen services were encountered or where the electricity was not available; or, where it was ineffective due to rubber gasketed couplings, new lead substitute joints in the intervening main pipe, or lack of capacity to thaw copper services, steam and hot water were used. One man can operate the steam outfits and do the thawing.

Steam is effectively used by generating it in a small portable boiler and feeding it under about 10 lbs. pressure through a ⅛-inch copper tube or 3/16-inch block-tin tubing. It is successful for only relatively short straight pipes where the steam jet can be advanced against the ice face as it melts. Where sharp bends are encountered and the tube cannot be advanced, the steam will not carry forward through the melted ice. Also, if the length of the service is too great the steam condenses in the tube before reaching the ice face and is not effective.

Hot water is, in general, more satisfactory than steam, though it requires two men to operate the equipment—one to push the tube into the pipe as the melting of the ice advances, and the other to operate the small force pump required. This method can be used on a longer service than the steam process and the hot water will carry farther beyond the end of the tubing when it meets an obstruction than does steam.

Small sections of 4-inch main about 75 ft. in length can be thawed by this method and if ⅜-inch iron pipe is substituted for the copper or tin tubing, the length that can be thawed can be approximately doubled. Where relatively new lead-substitute (compound) joints are encountered, preventing the use of electrical thawing, this becomes a valuable method of thawing larger mains also.



Sketch showing electric thawing equipment hook-up to thaw two services. One connection may be made to a fire plug, if convenient, when only one service is to be thawed. Before turning through the current the house piping is disconnected from the service line for safety.

Mobile Welding Generator Set Thawing Frozen Service Lines.

Time Required for Thawing

Experiences indicate that the time required for thawing services by all three methods varied through a wide range. Where equipment of adequate capacity was available for electrical thawing services were often thawed in from three to ten minutes and small mains in from one-half to two hours. Both hot water and steam thawing require a considerably longer time than this. However, in many instances, because of lack of experience and precedent, many jobs of thawing of both long services and mains were attempted without adequate equipment; and, as a result, two or three hours were often spent on a service and as long as ten or more hours on a main.

Cost of Thawing Operations

The cost of electric thawing was made up of many combinations of charges. In cases where hook-ups were arranged with the local power company, the charge was sometimes a stated amount per service or an hourly charge for the equipment, with or without a current charge. Welding outfits were supplied both on a per service basis and an hourly charge for men and equipment. The cost commonly varied between $2.50 and $7.50 per service for electric thawing, and the use of hot water and steam applications also came within this range. A common charge for welding outfits was $4.00 per hour, although it varied from $2.50 to $7.50 per hour.

Difficulties Encountered

One of the principal difficulties encountered in thawing by electricity has been the occasional inability to get a closed circuit through the pipe or main that will carry sufficient current to produce the required heat. The most common cause of this type of trouble is the presence of lead substitute joints in the section of main between the frozen service and whatever point is used for the circuit making connection. The weight of evidence from past experience appears to show that new lead substitute joints definitely will not carry sufficient current for thawing. Depending somewhat upon the character of the water, joints of this type in about five years will have formed, by corrosion of the iron in the bell and the material itself, a contact that will carry the current. This contact is somewhat fragile, however, and if too large an amperage is forced through it, it may burn through and break the circuit or create arcing and damage, after which other means than electricity will have to be used. To avoid this, it is necessary to keep the amperage below 200, or probably 150, and keep the current on for the extra time required. Rubber bushed repair couplings or joints are another reason for being unable to get a closed electric circuit, and, except in rare instances, time does not seem to produce a satisfactory current

*President of the American Water Works Association; former President, Community Water Service Co.

One of the Mobile Welding and Thawing Units—Ottawa, Canada, Water Department.

carrying contact unless much higher voltage is available than is needed for ordinary thawing work.

Failure to ascertain that there is no other path for the current to take than through the service line may lead to failure in thawing, even though the ammeter indicates that the proper amount of current is flowing. In some cases the current has taken a path through the house wiring and has heated the small wires (and BX cable carrying them) hot enough to set the house afire. It is not sufficient merely to detach the ground wire that is customarily found near the cellar wall, because other ground connections may be present elsewhere. *A complete disconnection of the piping system from the service line, by removal of a fitting or the meter, is the only safe course.*

Necessary Consideration in Successful Thawing

The thawing of services and mains by the use of electric current will be more uniformly successful if water works operators will bear in mind the fundamental characteristics of current flow and energy transference. Amperage is the measure of quantity of current flowing and is the most important element to consider because on the one hand the heating effect desired is principally dependent upon the flow of a sufficient number of amperes of current and, on the other hand, damage to joints and pipe is caused by too great an amperage. Voltage is the measure of electric pressure which is driving the current through the pipe. Voltage is therefore important only because of the amperage which it will force through the resistance of the pipe and joints. Ohms are a measure of resistance—i.e.—electric friction. The relation between the three is expressed as Voltage equals Amperage times Ohms. Thus, the greater the resistance, the greater must be the electric pressure (voltage) to force through a given amount of current.

Resistance, therefore, if it be in the joints, is a detriment to current flow and to the thawing. But the resistance of the material of the pipe to be thawed is useful in thawing, for ultimately it is the heat, produced by the force of the current, that melts the ice, and the greater the resistance, the greater the heat produced by a given amount of current forced through.

The transference of electric energy into heat in a conductor takes place according to a law first stated by James Joule, an English physicist. According to this law, the heat produced is directly proportional to the resistance of the conductor, the square of the amount of current and time the current is flowing. Thus it will be seen that a material which is a poor conductor and offers greater resistance to current flow will get hotter than one which is a good conductor. Also, a relatively small increase in amperage will greatly increase the heat produced as the variation is as the square of the amperage increment.

It would appear from this law that any difficult job of thawing could be done by merely continuing the current flow for a long period, and to a limited extent this is true, but it must be remembered that the heat produced in the pipe is immediately dissipated by the ice inside and the cold soil on the outside. Therefore, for any rate of heat production there is a point reached where it is dissipated as fast as produced; and, if in a reasonable time the pipe line is not thawad it is safe to conclude that too much of the heat is being lost through the soil and mere continuance of this condition for a longer time will not bring success. More heat must be provided and since the resistance of the pipe cannot be controlled, increased current flow (amperage) is needed. To secure this additional flow of amperes an increase in the electrical pressure (voltage) is necessary.

As a result of this law of Joule's, it can be seen that a copper pipe, being a good conductor, can only be heated by passing a considerable amperage through it and for a longer time than in the case of other materials (such as iron) which are not such good conductors. Comparing the resistance of the various metals used for water pipes, in order, copper is the least resistant. Considering copper as 1, steel is 7, wrought iron is 9, lead is 12, and cast iron is 73. Since copper has 1/7th to 1/9th the resistance of steel and iron and 1/12th that of lead, it is necessary to put through at least twice the amperage for approximately twice as long a time in order to thaw a length of copper service pipe as is required for the same length of steel pipe.

Experience

Experience has shown that from 200 to 400 amperes (varying with the diameter) will thaw iron, steel or lead services in from three to ten minutes. Depending upon the character of the connections, the type of joints in the mains and other elements of resistance, the voltage necessary to force such a current flow through the circuit will vary from 10 to about 60 volts. To thaw mains, amperages of from 400 to 700 are likely to be required at times. In view of the larger area of metal in these pipes it is fortunate that cast-iron has high resistance to current flow, else it would be impossible to produce sufficient heat with any practical portable electrical apparatus.

To produce a current of 400 amperes at 60 volts requires about a 25 k. w. generator, although one with a capacity of 30 k. w. is better. The gasoline engine driving it should have a rated capacity of at least 50 per cent more in order to sustain the output for several hours in case difficult main pipe thawing is encountered.

If current is taken from the 2300 volt lines of the local power utility and is stepped down to 110 volts, the transformers should have at least a total of 75 KVA capacity if mains are to be thawed, because it is occasionally necessary to use higher amperages than the average stated and also to maintain the current flow for several hours. A 25 KVA transformer is usually ample, however, for the thawing of services. It has been observed that AC current is more effective than DC in thawing because the vibration set up by the former is of material aid. The necessary small amount of melting near the pipe surface takes place with less actual temperature rise in the pipe.

Some Relationships Between Current Flow and Heat Production

1—*Kilowatt*
= 56.92 B.T.U. per min.
= 1.34 horse-power.

1—*Horse Power*
= 42.44 B.T.U. per min.
= 0.7457 KW.

1—*Horse Power/Hour*
= 2,547 B.T.U.
= 0.7457 KW.H.

1—*B.T.U. per Min.*
= 0.01757 KW.
=0.02356 H.P.

1—*Kilowatt/Hour*
= 3.415 B.T.U.
= 80.46 H.P.

ELECTRICAL PIPE THAWING*

By F. J. HIRNER

Harnischfeger Corporation, Milwaukee, Wis.

Only a few years ago was the arc welding generator employed for the first time in pipe thawing. Today many city water departments, plumbing contractors, as well as welding shops themselves, are finding this an exceptionally good method for freeing the pipes of ice quickly and economically. Here are some suggestions for building your own unit and the procedure to follow.

Any standard welding generator may be used for this purpose without alteration. Rugged construction, ease of operation, simple control and wide range of adaptability all tend to make the present-day welder ideal for this application. A gasoline-driven model welder is generally used because it is independent of electrical power facilities.

The method of thawing frozen water pipes by a flow of electrical current through the pipe has many advantages. The pipe is heated because of the resistance it imposes to the flow of the current. This eliminates the old, more expensive and slow methods of thawing pipes.

The pipe is warmed by the electrical energy being dissipated in the form of heat. Every form of metal which conducts electricity nevertheless offers some resistance to the flow of electrical current. This resistance causes a loss of electrical pressure (voltage) in pumping the current through the circuit. In mathematical terms, it is this loss of voltage times the current flowing which gives a product of watts of electrical energy converted to heat during its passage through the pipes. The higher the resistance of the pipe walls and the stronger the current flow the more rapid the heat production.

As to polarity, it makes no difference how the positive and negative lead wires are connected with respect to the pipe, but where water mains are involved, it is generally possible to connect the lead wires to fire plugs, curb service cocks and other similar points.

In the case of house service pipes, connection may be made to each side of the frozen pipe section so that the frozen part forms a part of the current circuit. Then boost the current indicator so that sufficient amperage passes through the frozen pipes.

It is not possible to state the exact current (amperes) and time required to thaw a given length of pipe. The type and size of pipe determine the maximum amperage that may be used. It is well to bear in mind that a lead pipe will melt at much lower temperature than a corresponding size of copper or iron pipe.

The condition of the soil, location of the pipe, extent of the freeze, the temperature of the air, the type and size of pipe, kind of joint and amount of current; all are factors determining the time required to thaw. However, the following table is indicative of current practice.

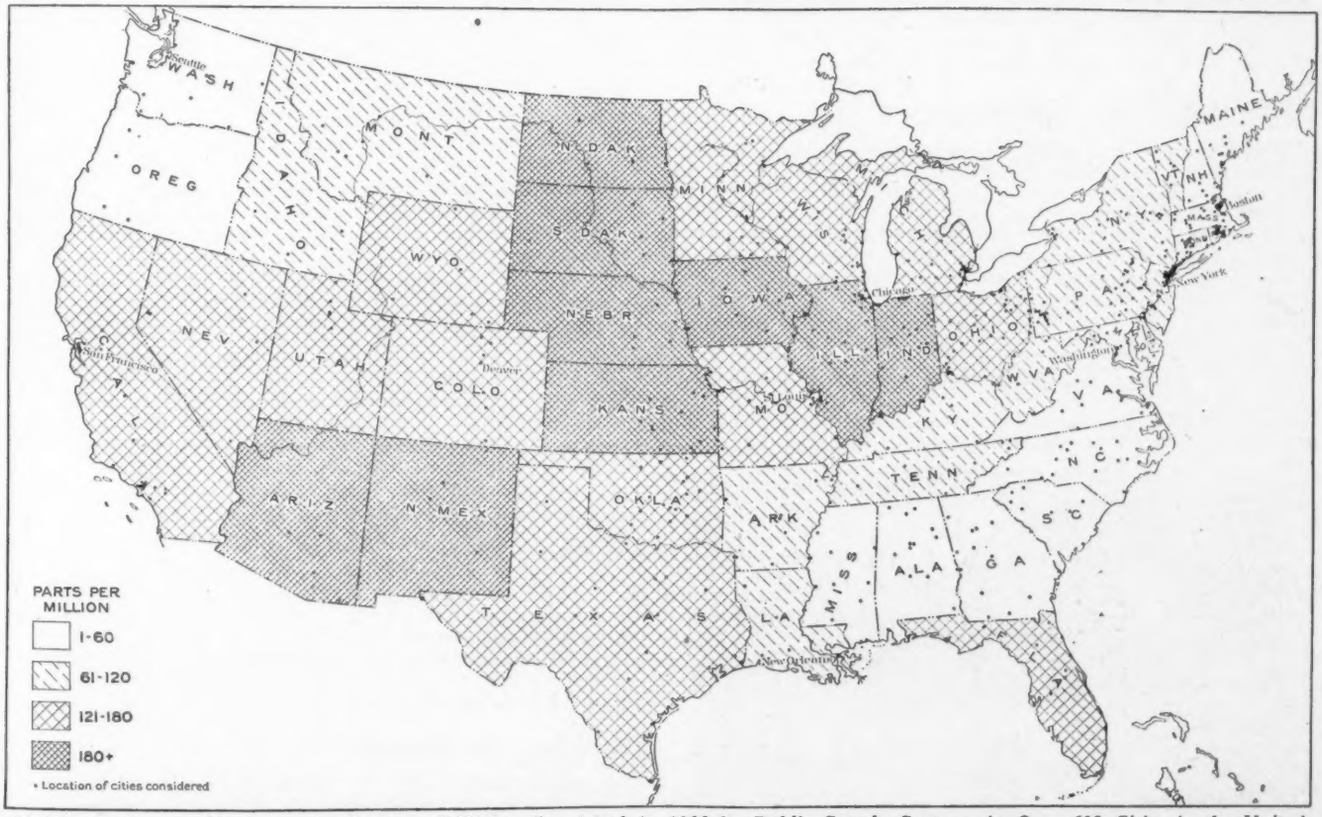
Size-of Pipe (Inches)	Recommended Current in Amperes	Approximate Minutes to Thaw
¼	70	14
½	120	21
¾	210	19
1	220	28
1½	300	31
2	340	39
3	410	58
4	500	74
6	500	118

(*See also table of "Effective Fire Streams," on page 181.)

Use welding cable of a size at least equal to that used for a similar current in arc welding. Care should be exercised to select cable of ample size, as otherwise, considerable energy will be wasted by heating the cables. If long cables are used, this is very important. Make all cable connections to generator and pipe as tight as possible and see that all rust, grease, scale, etc., are cleaned off the pipe at the point of connection with the cables. Connect the cables as close to the frozen spot as possible. In other words, have as little excess pipe in a circuit as possible. Pass no current through the water meter. Check the gas pipe system to make sure that its pipes are not in contact with the water pipes. When thawing pipes in a residence or building, first open the house lead-in electric service switch to prevent the possibility of a short circuit or some similar complication. It is also advisable to disconnect the radio ground wire, if connected to the water pipes.

The method described here is to give a general idea of the application of arc welders to an ever-increasing use—pipe thawing. It is a safe, efficient and economical way of meeting what heretofore was an unpleasant and costly situation. Naturally, the proceedings will have to be altered somewhat to meet the needs of each individual case.

*From Water Works and Sewerage, December, 1938.



Weighted Average Hardness, by States, of Water Furnished in 1932 by Public Supply Systems in Over 600 Cities in the United States (Reprinted from U. S. Geol. Survey Water Supply Paper—658)

REMOVING WATER FROM MAINS WITH COMPRESSED AIR*

Eliminates Pumping, Wet Trench, Loss of Time

By ROGER W. ESTEY[1] and NELSON BOARDMAN[2]

Danvers Water Works, Danvers, Mass.

Often in the repairing of mains or replacements of old pipe lines, the question of time is of paramount importance. The removal of water from these mains is many times a lengthy and most disagreeable part of the entire procedure. It often takes as much time to eliminate the water as it does for the connecting in of the new material.

Of course, today we have gasoline-driven diaphragm and centrifugal pumps that remove the water much faster than the old-fashioned hand methods. But, even with this more efficient and faster way of removing the water, it does not overcome the objectionable features, of water gushing out when the pipe is being cut in the trench. Sometimes where there are no blow-offs to remove the water entirely or take off some of the pressure that may be caused by the irregular contour of the ground, removing a piece of pipe from the line is a wet and disagreeable job. Besides this, all of the men have to be equipped with boots.

Another worry that goes along with such a job is the attention that has to be given to the soil conditions. If the nature of the soil is sandy and gravelly, any great amount of water in the trench may cause a slight washing or wearing away of the bank, causing either one or both banks to cave in. This is a very important part of the work to watch, because in many instances it is not possible to shut the water off any length of time without causing great inconvenience to the customers, and then there is always the fire hazard which must be given consideration. Any caving-in of the banks therefore naturally increases the time to complete the work. When the soil is clayey, water in the trench makes a nasty mess to work in, and it is nearly impossible to keep the pipe and fittings clean.

There have been many times when we have thought over the above undesirable conditions and wondered if there wasn't some way whereby this could be overcome. In several places we cut in blow-off lines, but since there are so many places requiring blow-off lines, this method seems both impractical and too costly.

Compressed Air Considered

Three things came to our attention that caused us to give consideration to the use of compressed air to remove water from the mains. One of us stopped in at a local garage, and while there a customer came in and asked for a gallon of denatured alcohol. The proprietor took the container and went over to a barrel and placed the container on top of the barrel, under a riser pipe, and opened the faucet. Much to our amazement, the alcohol came out so fast it was only a moment or two until the container was filled. After the transaction had been completed we inquired, "How is it that you get that pressure from the alcohol barrel?" He informed us that every now and then he would take the hose line used to pump up tires and put it on to another connection, on top of the barrel, and build up an air pressure in the barrel. When opening the faucet the alcohol would gush out. That gave me an idea.

[1]Superintendent and [2]Assistant Superintendent.
*From WATER WORKS AND SEWERAGE, June, 1936.

Compressor Connected to Hydrant

Removal of Water from a 12-In. Main

At about the same time one of us was called in at a private home which had a well supply. They had purchased a storage tank and pump unit. The tank contained approximately a thousand gallons. After the pump had filled the tank so that the gauge would indicate 60 lbs. it would only require about an hour before the pressure would drop so low that no water could be obtained in the house. It indicated that there must be a leak somewhere in the line. After testing for about an hour the leak was located out in the yard. This was later dug up and repaired. But what interested us was that almost 80 per cent of the tank from the bottom toward the top had a sweaty appearance on the outside and the upper part was dry. This indicated very conclusively that the upper 20 per cent was compressed air, and, from this, energy was obtained to force the water out of the tank and into the house.

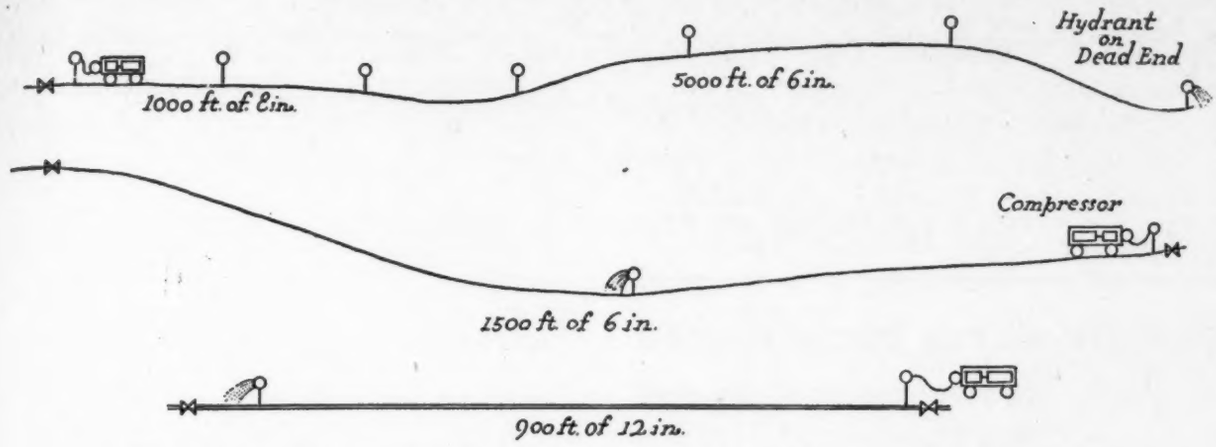
Now the third experience with compressed air followed almost immediately when we received a complaint from a customer that was receiving a large quarterly (metered) water bill. Since the bill was approximately $40 per quarter, and as the estate being supplied was of such large proportions, we assumed that it was legitimate consumption.

We immediately made an inspection. The pipe line consisted of about 1,200 feet of 2-inch cast iron cement-lined pipe with the meter in a pit at the property line. We inspected and tested the entire line with the exception of a swampy area of about 100 feet across it. We could not find a resemblance of a leak. The only place left was the swamp, which was covered with water. We thought we would try compressed air. We got our air compressor and placed it near the meter pit. We disconnected the meter and connected the air hose to the outlet pipe of the meter setting. We started up the compressor and turned the air into the pipe line and in about three minutes bubbles appeared out in the swamp water. We marked the spot with a stake and later, when the water receded, we dug it out and found the hole in the pipe that was responsible for the waste.

So, from these experiences, we felt that by applying compressed air into a pipe line and having a hydrant open, it would force the water out. With this thought in mind, it was not long before we had an opportunity to try out our idea, and it exceeded our fondest expectations. We have used it several times lately, so successfully that we have told some of our friends about it and they too are highly pleased with the results.

Procedure Developed

In making connections, the lay-out must be looked over carefully to find the highest place possible on the section to be emptied and there connect in the air. Then the hydrant at the lowest point must be opened wide. It is not necessary to close off any services.



Sketch Showing Three Conditions Wherein Water Removal with Air Compressors Was Successful

When the district is shut off and the air compressor is connected, either to a hydrant or house connection, and the relief hydrant is opened, turn the air into the main, and almost instantly the water will start coming out of the waste hydrant. The compressor that we employ normally indicates 100 lbs. when the tank is full. The pressure will almost immediately drop from 100 lbs. to 60 lbs., and sometimes will gradually drop to 40 lbs., depending upon the size of the pipe. The larger the pipe, the greater the drop in pressure.

Some Experiences

Our outstanding performance was in connection with the emptying of a long line consisting of 1,000 feet of 8-inch pipe and about 5,000 feet of 6-inch, terminatnig in a dead-end district.—See sketch. In this section we had planned several changes and we had seven holes dug. One was for the laying of a 6-inch line across this street. Three hydrants had to be moved back and gates cut in on the branches and three extra gates cut into the main line. We connected up our compressor to the first hydrant

Removing Water from 6-In. Main by Air Pressure. Section 480 Ft. Long Emptied in 3 Minutes

and opened up the last hydrant at the end of the line. We closed off the district at 8 a. m. and then turned the air into the line, and in thirty-five minutes the water was forced out, and air then came out of the last hydrant, indicating that the water was removed. During this thirty-five minutes the water came faster and faster, due to the fact there was progressively less water and less weight to push with each succeeding minute.

During the day we cut into this pipe line in seven places and none of the openings had enough water in them to even require common rubbers over the shoes. In fact, six of them were *completely* dry. You can readily see the value of this procedure. It is inexpensive, quick, and in most instances a dry trench can be had. You can well imagine how long it would have taken to complete the job if the cuts were made and hand or gasoline pumps had been used in the removal of the water from the trench.

Another experience on a 6-inch line 1,500 feet long was interesting in that a hill was within the area. Half way along the line at a low point there was a hydrant which was used to remove the water. At one end of the line was another to which we connected our compressor line. This hydrant was about 5 feet higher than the hydrant we were to blow the water out through. At the other end of the section of line was the gate, located at a point about 25 feet higher than the hydrant which was to be used to blow out the water.—See sketch. After closing the gate the two hydrants were opened and the compressor turned on. In a very few minutes the water ceased to flow and air came out of the hydrant. The compressor was closed off for about a minute, which allowed the water on the hill to flow down into the lower area. Then the compressor was turned on and more water gushed out. This procedure was repeated several times until no more water came out of the hydrant. The tee was then cut into the line and pipe laid to a gate. At no time did water come out of the cut pipe.

This scheme has also worked out satisfactorily on a 12-inch pipe line of about 900 feet in length and nearly level.

We have also located the ends of our two intake suction lines from our two sources of supplies. At our main station we have a connection around our well house connected into our discharge system in order to reverse the flow of water in the suction line. There was a connection wherein we could connect our compressor. After closing the gate on the suction line in the well house the air was turned on and bubbles appeared all along the line for about 300 feet out into the lake. When the air reached the end of the pipe it then came to the surface, causing the water to bubble up sometimes 2 feet above the surface. It showed very conclusively the location of the pipe and the end of it.

This method of removing water from pipe lines has eliminated all physical effort in securing a dry trench and has materially speeded up the work. It is inexpensive and almost always leaves a dry pipe and trench.

Standards of Practice

The Indianapolis Water Co., Indianapolis, Ind., keeps a code-book which outlines procedure in all kinds of situations, even to specifying the kind and color of paint to be used in various places. The "code" could never be complete because of changes from time to time, as conditions warranted. However, it served as a valuable guide and a record of previous decisions.—*Monsanto "Chemical Topics."*

Dry Ice as Well Cleaner

Dropping 200 pounds of dry ice down a well casing and thereafter closing the well tight, a well driller has found effective in opening of well screens. As the dry ice "melts," the liberated carbon dioxide gas builds up a pressure which forces the water in reverse of usual flow out through the well screens and surrounding sands or gravel. The pressure is watched on a gage on the well and the relief valve is opened to avoid pressures above 150 lbs.—*Monsanto "Chemical Topics."*

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Executive Offices: 22 E. 40th Street, New York, N. Y.

Offices in all large Cities

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TRANSITE PRESSURE PIPE — TRANSITE SEWER PIPE

FOR YOUR WATER DISTRIBUTION SYSTEMS - - -

TRANSITE PRESSURE PIPE will reduce your Operating, Maintenance and Installation Costs—assure permanently efficient, economical water transportation through the years!

You save all ways when you install Transite Pressure Pipe—for in addition to low first cost and rapid, economical installation—it is remarkably resistant to all the destructive agencies encountered in service. Being non-metallic, Transite is entirely unaffected by electrolysis and tuberculation—the internal corrosion that cuts down flow rates and increases pumping costs—and it is highly resistant to all forms of corrosion.

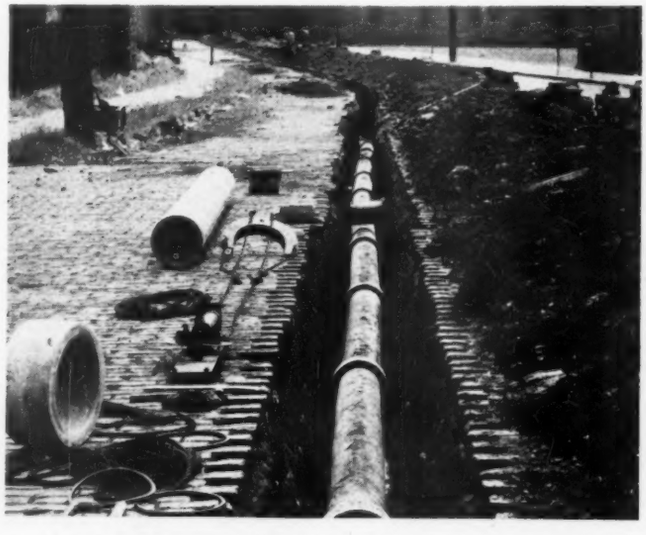
Manufactured in a wide range of sizes—from 2 to 36 inches inclusive—and in pressure classes of 50, 100, 150 and 200 lbs., it is composed of an intimate mixture of asbestos fibres and cement, formed under tremendous pressure, on a polished steel mandrel, into a tough, dense, homogeneous structure of great strength and uniformity.

TRANSITE CANNOT TUBERCULATE

The smooth interior surface imparted to Transite Pipe by the mandrel on which it is made offers minimum resistance to the flow of water. Numerous tests have proved that the conservative minimum flow coefficient for Transite lines in service is C=140. Some outstanding Water Works authorities report coefficient values on asbestos-cement pipe from 142 to as high as 165.

W. S. Pardoe, Professor of Hydraulic Engineering, University of Pennsylvania reported in an article "Tests of Cement-Asbestos Pipe" (Engineering News-Record, Jan. 28, 1926): "These

Because it is immune to tuberculation, wherever used, Transite Pipe assures an abundant supply of water through the years with low pumping costs.



Transite's remarkable resistance to all forms of corrosion, due to its asbestos-cement composition, assures long life and low maintenance costs.

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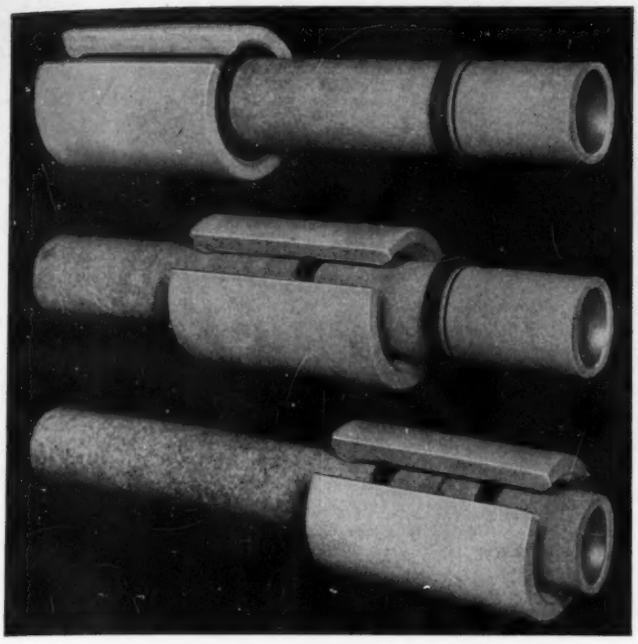


In the above illustration of the Simplex Coupling, the Transite sleeve has been cut to show how the rubber rings are compressed between the sleeve and the pipe. Top: rings and sleeve at start of operation. Center: sleeve pulled over one ring. Below: final position, sleeve centered over joint.

figures indicate that the cement-asbestos pipe will discharge 15% more than clean cast-iron and 45% more than slightly tuberculated cast-iron pipe."

High coefficient values such as these are a permanent feature of Transite Pipe—because, being non-metallic, Transite *cannot tuberculate!* The interior wall remains smooth indefinitely—its initial high delivery capacity is permanently maintained. This assures virtual freedom from excessive pumping costs, reduced pressures and the expense and inconvenience of periodic cleaning.

HIGHLY RESISTANT TO CORROSION

One of the important advantages of Transite's asbestos-cement composition and unusually low free-lime content is its high resistance to external corrosion. Practically unaffected by all active agents in the strength encountered underground, Transite assures large economies in maintenance even when laid under conditions that rapidly destroy other materials.

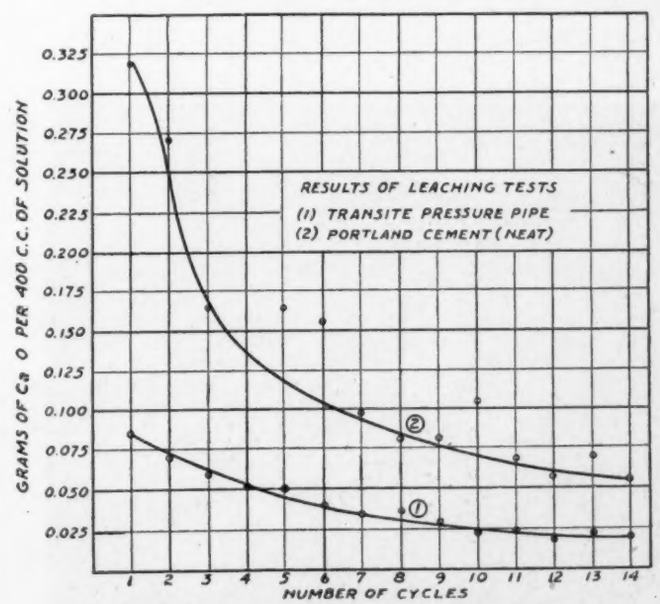
Although there is a certain amount of free lime in ordinary neat cement which may be affected by corrosion, in Transite this free lime is converted into insoluble silicates by a special curing process—thereby greatly increasing its natural chemical stability.

Thousands of installations of asbestos-cement pipe all over the world, laid in all kinds of soil and carrying all types of water, attest to Transite's exceptional resistance to corrosion, its low maintenance cost and permanent efficiency.

LOWER INSTALLATION COSTS

Savings in installation costs with Transite Pipe begin at the very outset. Because of its long 13-foot lengths, relatively light weight and speed of assembly, it is rapidly, economically installed, even by unskilled workmen. More footage may be carried per truck load, fewer men are required for every handling operation and no mechanical equipment is required except for the very largest sizes.

The ease and speed of assembly of the Simplex Coupling used in Transite Pressure Pipe lines is one of the major factors contributing to installation savings. Consisting of a Transite sleeve and two rubber rings, these bottle-tight joints are easily assembled in much less time than that re-



The chart above represents a series of leaching cycles for both pulverized Transite Pipe and neat cement. The small amount of free lime extracted from Transite indicates that for all practical purposes it may be considered insoluble—one of the major factors responsible for its unusual resistance to soil corrosion.

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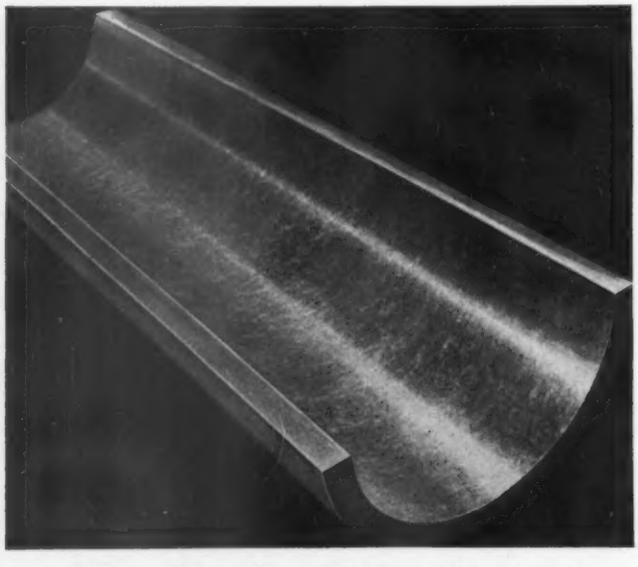
quired by ordinary types of joints. It is not necessary to maintain heating equipment at various points on the job, for the Simplex Couplings are assembled cold just as they are received from the factory—a simple hydraulic coupling puller is the only tool required.

Not only do these couplings permit faster installation and tight joints, but they also provide a desirable flexibility in the line to accommodate ground movement and prevent breakage. Furthermore these flexible, bottle-tight joints permit laying the pipe on long curves without the use of special fittings.

Because of the tough, dense structure of Transite Pipe, it may be drilled and tapped perfectly with standard tapping tools and methods. The deep, clean threads are strong and firm. They provide perfect seating for threads on corporation stops and eliminate leakage at these points.

LOWER MAINTENANCE COSTS

Because Transite Pipe is absolutely immune to tuberculation and electrolysis and highly resistant to all forms of soil corrosion, it provides the best assurance of permanent freedom from cleaning expense, shutdowns and costly renewals. Bottle-tight Simplex Couplings minimize underground leakage and prevent the breaks in mains due to undermining of pipe by joint leakage.



Because Transite is non-metallic, its original smooth interior surface remains permanently unaffected by the destructive, choking effects of tuberculation.

The absence of large bell holes at joints permits the use of narrow, less expensive trenching as is well illustrated by this installation of 6" Transite Pipe.

LOWER PUMPING COSTS

Added to the substantial savings in installation and maintenance are the even greater savings in pumping costs, due to the constant, unchanging high delivery capacity of Transite Pipe, and the extra advantage of bottle-tight joints that prevent wasted water and reduced pressure due to leakage.

And yet, with all these points of superiority, Transite Pipe costs no more, installed, than other types of water pipe.

WRITE FOR COMPLETE DETAILS

For further information on how this modern, permanent water carrier can save you money through the years, write for the free, 36-page, Transite Pressure Pipe Brochure, TR-11A. In addition to complete details on how Transite Pipe will cut your installation, maintenance and operating costs, this illustrated brochure contains excerpts from the Underwriters' Laboratories Report on Transite Pipe, the unbiased opinions of scores of users throughout the country and a wealth of other information vitally important to everyone interested in the more efficient operation of water distribution systems. Ask, also, for the interesting set of Hydraulic Tables based on Hazen and Williams figures, which demonstrate the effect of tuberculation on pumping costs through five to twenty years of service.

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AND IN YOUR SEWAGE DISPOSAL SYSTEMS - - -

TRANSITE SEWER PIPE will increase the efficiency of your system and reduce expense to an absolute minimum!

Manufactured under extreme pressure in the same manner as Transite Pressure Pipe, and made of the same permanent, non-metallic minerals—asbestos fibre and cement—Transite Sewer Pipe is establishing an enviable record for economy and efficiency in sewage disposal systems. Furnished in a wide range of sizes—from 4 to 36 inches inclusive, and in both single and double strength, its many outstanding advantages over ordinary sewer pipe set it apart as being the ideal material for this service.

LONG LENGTHS, LIGHT WEIGHT REDUCE INSTALLATION COSTS

The long 13-ft. sections in which Transite is furnished eliminate the difficulties in installation and maintenance common to ordinary short length sewer pipe. Strong, durable, yet comparatively light in weight, these long sections cut handling costs to a minimum. More footage may be carried per truck load to the trench, fewer men are required to install the pipe and no mechanical equipment is needed except for the very largest sizes. These long lengths reduce the number of joints in the line (only 1/3 to 1/4 as many joints as with ordinary short length pipe) and thus save considerable time and labor.

Transite, the corrosion-resistant, asbestos-cement sewer pipe, answers every requirement of efficient sewerage service. Its long 13-ft. lengths make laying to exact grades a quicker and more accurate job. And the tight joints employed minimize infiltration.

In addition, long lengths are more easily laid to a line and resist the tendency to slip out of alignment; therefore, they greatly facilitate laying the pipe to an accurate grade.

TIGHT SLEEVE JOINTS REDUCE INFILTRATION

The poured sleeve joints used in Transite gravity flow lines reduce infiltration to a minimum and with this type of joint there is no bell to break off—the sleeve extends over both lengths of pipe, providing twice the flexibility possible with other types of joints.

The ends of all pipe and the inside of all joint sleeves are *double*-primed at the factory with a specially developed primer that assures greatest adhesion between pipe and compound.

The jointing compound used is the highest quality, unfilled asphalt. It is strong, flexible, easily poured and is not subject to cold flow. Unaffected by temperature changes, this compound provides strong, tight joints that minimize root growth, and the infiltration of ground water and silt that cuts the sewage-carrying capacity of ordinary pipe.

The Simplex Couplings used on Transite force mains provide a rapidly installed, permanently bottle-tight joint that eliminates leakage.

REDUCED MAINTENANCE COSTS

Transite's unusual resistance to all types of corrosion—inside, outside and all the way through—has been proved by a large number of installations serving under a wide variety of conditions. It is virtually unaffected by the action of hydrogen-sulphide gas and other destructive agencies found in sewage. In Transite, the free lime found in ordinary cement products is converted into insoluble silicates, thereby greatly increasing the natural permanence and corrosion-resistance of this asbestos-cement pipe. Its smooth interior surface gives a higher sewage flow and minimizes the labor cost of flushing.

For complete details about this modern sewer pipe write to Johns-Manville, 22 E. 40th Street, New York, N. Y.

JOHNS-MANVILLE JM PRODUCTS

CUTTING CAST-IRON PIPES*

By Unique Method Developed in Atlanta

By W. M. RAPP

Superintendent, Construction and Distribution, Atlanta, Georgia
(Honorary Member A.W.W.A.)

In brief, the method of pipe cutting, to be described, consists of drilling a circle of holes around the pipe and placing tapered wedge pins in each. Then, driving these up in sequence until the split once started, from hole to hole, travels the circumference of the pipe rapidly. The result is a "ripped" line of neat breaks from hole center to hole center.

The following has been drawn from a report by J. N. Eley, consulting engineer, which is a first-hand account of one pipe-cutting job done for Buford, Hall & Smith, Atlanta contractors, in connection with the construction of one of Atlanta's new sewage treatment plants.

The pipe cut was a standard length of 54 inch Class B Cast-Iron pipe produced by U. S. Pipe & Foundry Co.

For the job, the contractors used their truck mounted Worthington air-compressor unit, having a capacity of 105 cfm. at 100 lbs. pressure. The balance of the needed equipment was loaned by the Atlanta Water Department, and consisted of the following:

An Ingersoll-Rand, Size B, Non-Reversible Air Drill, mounted in a frame with hand feed, chains and toggle-level locking device, designed by Mr. Rapp. (See picture.)

An adjustable pipe scriber; two track-levers, used in pinch-moving freight cars, for turning the large pipe; the required number of round tapered pin wedges, having opposite faces slightly flat for reasons later obvious; two sledge hammers.

(Note—The same equipment used for cutting the 54 inch pipe is also used on all pipes between 12 and 60 inch diameters.)

The crew making the cut consisted of: One compressor operator, one handy man, three colored laborers. One of the latter was a veteran employee of the Water Department, but none of the remainder of the crew had ever seen the method used before.

The Procedure

Because of the boggy nature of the ground, the length of 54 inch pipe was first rolled onto 8 x 8 pine skids. This facilitated turning it with the freight car moving-levers through various degrees, to make scribing, drilling and wedge driving easier. With the adjustable scribe a drill guide line was scribed around the exterior circumference and centers, for the 1 inch holes to be drilled, were marked with a center punch.

The air operated drilling machine was then set up on the pipe and connected to the compressor air lines. The drilling then proceeded around the scribed line. For convenience and neater and faster work, by inexperienced workmen, the pipe was turned about 33 degrees, at intervals, to keep the drill in a more nearly vertical position.

Wedge Driving

The drilling completed, pin-wedges were tightly set in 33 of the 45 holes by hand hammer. The flat edges faced with the line. Then began the sledging, or the driving-up operation. Starting with pin No. 1, full force blows were struck each odd number pin in sequence—3, 5, 7 . . . 33. From pin 33 the driving-up was reversed with the sledging of the even number pins, 32, 30, 28 . . . 2, in sequence. After two minutes (less 5 seconds) of this procedure a fracture, approximately 12 inches long, showed up from pin 5 to pin 8. After 45 seconds more of sledging the fracture had extended half-way around the pipe. The pipe was then pinch-rolled forward and pins were inserted in the 12 remaining holes, thus brought into position. Sledging of alternate pins was resumed in sequence, as before, and after another minute (plus 3 seconds) the end bell dropped down and the job was complete.

How successful the operation was, is shown in the accompanying pictures revealing the clean and regular fracture straight through the 1.9/16 in. pipe walls, and departing but little from either side of the scribed line. No horizontal fractures, radial to the holes, appeared. The absence of chipping and projection is likewise worthy of note.

*From WATER WORKS AND SEWERAGE—August, 1937.

Time Consumed

A careful stop-watch record was kept of the time consumed in the several operations. A recapitulation follows:

Operation	Min.	Sec.
Scribing (drill line)	3	55
Rolling pipe (total)	6	14
Center punching (on line)	10	42
Setting Machine (on line)	5	57
Drilling (45—1 in. holes)	35	56
Backing and resetting drill	26	53
Removing machine (from pipe)	0	41
Setting Tapered Wedges (45)	2	10
Driving-up wedges	3	48
Throwing the bell	0	15

Total consumed time—1 hour, 36 min., 31 sec.

Costs:

Compressor operator ($1.00 hour)	$1.61
Handy man (75 cents hour)	1.21
Two laborers (40 cents hour)	1.29
One laborer (52 cents hour)	.84
Total labor cost	$4.95
2.41 gals. gasoline at 22 cents gallon	0.53
Total cost of cutting 54-in. Class B pipe	$5.48

Drilling Completed and Pin-Wedges Set Ready For the Boys to Let Loose With the "Persuaders." After 3 Minutes and 48 Seconds of This Staccato, Here's the Result Below.

WATER WASTE SURVEYS

By A. D. STALKER*

Waste control, as a subject, can be divided very conveniently into two parts: First, that having to do with wastage which takes place inside houses and other buildings; and second, that concerned with wastage from the underground portion of the distribution system.

Meterage as a Remedy

By far the most effective method of dealing with the wastage that takes place inside buildings is by having services 100 per cent metered.

In cities or towns where none, or only a small percentage of the services are metered, the control of waste from defective plumbing fixtures is much more difficult. Systematic house-to-house inspection, regularly maintained by a permanent staff of inspectors, will prove a great aid in keeping this class of waste within reasonable bounds. These inspections must be frequently repeated, and to be effective must be supported by strong laws and good plumbing ordinances.

The public in general seems to think that the information contained in educational literature dealing with the importance of attending to small leaks and wastes should make a great impression—on somebody else. The value of this type of waste-control work is debatable. The writer's opinion is that the results obtained are not worth the trouble and expense of getting up and distributing the literature. *The only cure for waste due to carelessness is metering.*

The Pitometer

The second phase of waste reduction has to do with the location of leakage from the underground portion of the distribution system. To find the leaky parts of the underground system, a survey must be made to ascertain where the water goes after leaving the pumps, and what parts of the system receive excessive quantities. This can be accomplished by means of a pitometer.

The pitometer is an instrument that adapts the "Pitot" principle to the measurement of water. Two tubes enclosed within a metallic sheath are introduced into a water main through a 1-in. corporation cock. The tubes are set in such a position that one orifice faces directly up-stream and the other directly down-stream. They are connected by means of rubber tubing to the two legs of a glass U-tube containing a liquid of a specific gravity higher than water and which will not mix with it. The difference between the pressure on the downstream and on the up-stream orifices, which is the pressure due to velocity, causes a deflection of the liquid in the arms of the U-tube, and from this deflection the flow is calculated.

The prism photo recording pitometer makes a continuous photograph of the U-tube fluctuations upon a sheet of sensitized paper attached to a drum revolved by clock-work. The drum can be geared to complete a revolution in 12, 24 or 48 hours. From this photo record the flow through the main can be ascertained for any time during the gauging.

To measure accurately the flow through mains with the pitometer, the ratio of the mean velocity to the center velocity must be established, as the orifices of the instrument are set at the center. This ratio is called the "pipe coefficient" and is established by traversing the pipe. A pipe traverse is made by taking readings of the velocity at intervals across the pipe sufficiently close together to make a smooth curve when plotted. The pipe section is divided into rings of approximately the same area. The mean velocity of each ring in feet per second multiplied by the area of the ring in square feet, gives the ring volume in cubic feet per second. The mean velocity for the whole pipe section is the total of these ring volumes divided by the area of the pipe. The mean velocity divided by the center velocity is the pipe coefficient. On large mains it is desirable to traverse the pipe on two diameters 90 degrees apart and in the same plane. By using two rod meters, one can be left at the center of the pipe and the traversing done with the second, and readings taken when the center velocity is the same in each case. The pipe coefficient is the same for all velocities in the same pipe at any particular point, and it is upon the discovery of this principle that all pitometer gaugings are based.

*The late Prin. Asst. Water Works Engineer, Ottawa, Ont.

How Pitometer Survey Is Made

A pitometer survey should properly start at the pumping stations, and the discharge from the pump checked. When this has been done, I think it good practice to test all trunk or feeder mains before dividing the system into districts. These mains taken separately can be quickly done, and the distribution of water through that part of the system fed by them is interfered with for a much shorter time than would be the case if they were to form part of a district. Furthermore, trunk mains are usually so spaced as to form excellent district boundaries.

More accurate results can be obtained if the pitometer tap is placed on a small main feeding into the trunk main than would be the case if the tap were to be placed on the trunk main itself, as a flow that would cause scarcely any deflection of the liquid in the U-tube if the tap were on the large main, would cause a sufficiently great deflection to give an accurate measurement of the flow if the tap were on the smaller main. The tap may be placed in such a position as to serve as a gauging point both for the trunk main and one of the districts.

The next step is the dividing of the system into districts. This work must receive careful consideration. A district should be of a size that can be conveniently sub-divided in one night during the hours of minimum consumption, and the boundaries laid out with a view to causing as little interference as possible with the circulation through the balance of the system. The gauging point should be on a main of such a size that a velocity of about 4 ft. per sec. would supply the maximum normal demands of the district, without any allowance for leakage. This velocity will give a deflection of about 17 in. on the U-tube, using a liquid of 1.25 specific gravity. The maximum consumption would not be likely to cause a velocity great enough to blow the liquid out of the tube, and the minimum consumption would cause a fairly high deflection. When the district is first gauged, a velocity higher than the above will probably be recorded ,and a heavier liquid might have to be used. The idea behind choosing a main of this size is to ensure a deflection high enough to give an accurate measurement of the flow when all leaks have been stopped.

If the survey being made is an original one, a 48-hour record should be taken, including a Sunday if possible. Very careful records should be kept of all flows recorded and work done, and of any peculiar or unusual conditions that may be found to exist, as this information will, without doubt, be of great assistance in later surveys. Weather conditions and any circumstances which might affect the consumption of water should be noted.

When the flow is to be gauged, the district is cut off from the rest of the distribution system by closing all the valves on the boundaries, excepting on the pipe to which the instrument is connected. To make sure that the valves are holding properly, and that no water is getting in, either through them or through services that may be joined up inside buildings and connected to mains on both sides of a boundary, the main feeding the area enclosed should be closed and a hydrant at the highest point within the boundaries opened. If the hydrant is not off, the point at which the water gets into the district must be located, and the flow stopped. When it is assured that the whole supply passes through the main to which the instrument is connected, the district is ready for the taking of the record. Precautions should be taken to prevent street flushers drawing water from hydrants located within the district boundaries while the record is being taken. It is advisable also, to have a man with a valve key stationed at a fire hall either in or convenient to the enclosed area, so that valves could be opened with as little delay as possible in the event of a fire breaking out. If a fire occurs in a district while the flow is being recorded, the record will be ruined, and opening the boundary valves cannot make it any worse.

If the record taken indicates that an excessive amount of water passes the gauging point, and that the flow remains high during the hours in which very little water would be used, the district should be sub-divided. For subdivision purposes the mechanism revolving the drum of the pitometer is geared to complete a revolution of the drum in twelve hours. This will give a movement of an eighth of an inch in five minutes.

One method of sub-dividing is to divide the whole district into

sections as small as the spacing of the valves will permit, and then closing a section down for a short period (at least five minutes) and re-opening it, and repeating this operation with other sections, until all have been shut down. Another method is to start at the boundaries and work towards the instrument, gradually reducing the size of the district, and as the new boundary valves are closed, the old ones are opened. The method used will depend on the conditions that exist in the district. With either method, the time each shutdown is completed must be noted. It is important that all valve operations should be checked over before leaving the district, to make sure that no valves are left closed.

Locating the Leaks

When the subdivision record has been interpreted we will know the quantity of water each section of the district received. The sections that receive excessive quantities should be carefully gone over and the reason for the large flow ascertained. It is a good idea to have a plumbing inspector make a special examination of the fixtures in all buildings in these areas. If this inspection fails to account for the flow, it is assumed that the cause is underground leakage.

There are a number of methods usually employed to give the exact location of underground leakage. The one most generally used, and the one by which a great majority of leaks are found, is by sounding. There are a number of instruments on the market devised to help in picking up sounds, and those that I have used have proven of great assistance. The procedure is to sound all the valves, hydrants and services in the suspected area, and sometimes it is possible to get closer to the source by driving rods down to the main. It is remarkable what an experienced man can accomplish by sounding. In a great many cases he can not only tell where the leak is, but its nature—whether it is a blown joint, a split main, or a burst service pipe.

There are, however, a number of cases in which the sounds picked up are confusing. Where there are two or more leaks close enough together for the sounds to overlap, it is difficult to isolate the sound from one leak and trace it to its source. Leaks that discharge under water produce a sound that is often misleading. Then there is the abandoned service that has not been properly blanked at the main.

Other methods used in conjunction with sounding include testing the pressure at different points until the point of minimum pressure is located; noting the flow in sewers at the manholes; pounding the road surfaces to endeavor to locate cavities beneath the pavement, and searching in cellars and excavations for dampness.

If the above expedients fail to locate the leak, the primitive of digging is resorted to. It is quite probable that the first hole put down will not be in the right place, but from the conditions that exist at this point, a second hols is usually all that is necessary.

Water appearing any place should be looked on as a possible leak, if the reason for its appearance is not apparent.

Other Duties of Waste Reduction Department

In addition to the work outlined above, it is the duty of the department in charge of waste reduction to attend to all cases of flooding of cellars. The first thing to be done in these cases is to find whether or not the water department is responsible.

When serious breaks occur in the distribution system they usually give plenty of surface indication as to their locality. These are attended to by the trouble department. Bad breaks do occur without giving such indication, however, and these are followed up by the waste-reduction department. In such cases, the department first gets in touch with all the fire halls in the city, each of which has a pressure gauge installed, to find if possible an area in which the pressure has dropped. If no indication is given in this way, men are sent out to go over those parts of the system where it would be possible for the water from such a break to escape without surface indication.

The Pitometer Company

Water Distribution Engineers

50 CHURCH ST. — **NEW YORK, N. Y.**

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Chicago, Ill.
Detroit, Mich.

THE X-RAY FOR PUBLIC WATER SYSTEMS

Branch Offices
Albany, N. Y.
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OFFER THREE IMPORTANT SERVICES FOR WATER SUPPLY SYSTEMS

1. WATER WASTE SURVEYS

locate hidden leaks and other sources of water waste, accounting for all the water that enters the distribution system. See Pitometer Bulletin No. 17.

2. TRUNK MAIN SURVEYS

ascertain which mains are overtaxed with resultant loss of pressure, and which mains are not doing all the work for which they were designed. See Pitometer Bulletin No. 18

3. DISTRIBUTION SYSTEM STUDIES

determine necessary extensions and replacements to meet present needs and future requirements over a twenty-five year period. See Bulletin No. 18.

Send for Bulletins No. 17 and 18 — Full information on request

UNITED STATES PIPE AND FOUNDRY CO.

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Makers of

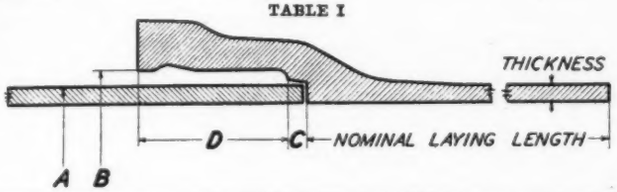
SUPER-DE LAVAUD CENTRIFUGALLY CAST IRON PIPE
PIT CAST IRON PIPE AND FITTINGS
THREADED PIPE IN IRON PIPE SIZES
WEBRE INDUSTRIAL AND SUGAR APPARATUS
USICAST CHEMICAL CASTINGS

U. S. JOINT PIPE AND FITTINGS
FLANGED PIPE AND FITTINGS
FLEXIBLE JOINT PIPE
LARGE CASTINGS TO ORDER
USICAST CAST IRON ROOF

Super-deLavaud Pipe with B&S Joints

Super-deLavaud Pipe with bell and spigot joints is available in all sizes from 3″ to 24″ and in 12-foot and 18-foot lengths. The joint is particularly adaptable for lead, cement, joint compound or rubber ring assembly. The centering ring insures easy alignment and uniform distribution of the jointing material. The process by which this pipe is produced assures concentricity, evenness of metal and freedom from sand or slag inclusions. The bell and spigot joint, made with lead or other jointing materials, shows ample strength to resist pulling apart. If required to meet service conditions, pipe will be furnished with special linings. All Super-deLavaud Pipe with bell and spigot joints are made to meet Federal Specification WW-P-421. Write for descriptive booklet.

TABLE I



Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length			
			12-Foot Length		18-Foot Length	
			Weight of Pipe Pounds	Weight Per Foot Including Bell	Weight of Pipe Pounds	Weight Per Foot Including Bell
3	150	.33	140	11.8		
3	250	.36	155	12.8		
4	150	.34	195	16.4	285	15.9
4	250	.38	220	18.4	325	17.9
6	150	.37	315	26.3	460	25.5
6	250	.43	350	29.3	515	28.5
8	150	.42	475	39.4	690	38.3
8	200	.46	510	42.4	745	41.3
8	250	.50	545	45.5	800	44.3
10	150	.47	640	53.3	935	51.8
10	200	.52	700	58.3	1025	56.8
10	250	.57	760	63.3	1115	61.9
12	150	.50	810	67.4	1180	65.6
12	200	.57	905	75.4	1325	73.7
12	250	.62	990	82.5	1450	80.7

Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length			
			12-Foot Length		18-Foot Length	
			Weight of Pipe Pounds	Weight Per Foot Including Bell	Weight of Pipe Pounds	Weight Per Foot Including Bell
14	100	.48	920	76.5	1340	74.3
14	150	.55	1060	88.5	1555	86.3
14	200	.62	1190	99.0	1735	96.3
14	250	.69	1320	110.0	1930	107.3
16	100	.52	1130	94.2	1645	91.4
16	150	.60	1320	110.2	1935	107.4
16	200	.68	1490	124.1	2175	120.7
16	250	.75	1635	136.1	2390	132.7
18	100	.56	1365	113.8	1990	110.6
18	150	.65	1595	132.8	2330	129.6
18	200	.74	1810	150.9	2645	146.9
18	250	.83	2015	168.0	2950	163.9
20	100	.58	1585	132.0	2305	128.0
20	150	.68	1860	155.0	2720	151.0
20	200	.78	2125	177.1	3105	172.4
20	250	.88	2365	197.1	3465	192.4
24	100	.64	2085	173.8	3035	168.6
24	150	.76	2480	206.8	3630	201.6
24	200	.88	2855	237.8	4170	231.6
24	250	1.00	3200	266.8	4690	260.6

Threaded Cast Iron Pipe Centrifugally Cast

Super-deLavaud Cast Iron Pipe is now being manufactured in "iron pipe sizes" with threaded joints to meet the demand for a better and more durable pipe. There are two distinct types of service for which Super-deLavaud Cast Iron Pipe may be used: pressure service for water, gas, steam or similar liquids and gases; and drainage service. Pressure pipe is made to meet the requirements of Federal Specifications WW-P-421 and is supplied in three classes: standard, extra-strong and double-extra-strong. Drainage pipe, used for waste, vent and drain work, is a lighter pipe for use in buildings and elsewhere where a tight screw-coupled joint is needed. Drainage pipe is made to meet the requirements of Federal Specifications WW-P-356.

THREADED CAST IRON PRESSURE PIPE

(Made to meet the requirements of Federal Specifications WW-P-421)

Size Inches	Class	Nominal Length, Feet	Outside Diameter, Inches	Nominal Thickness, Inches	Threads per Inch	Weight per Foot Pounds
3	Standard	12	3.50	.36	8	11.08
	X-strong	12	3.50	.45	8	13.45
	XX-strong	12	3.50	.48	8	14.21
4	Standard	18	4.50	.38	8	15.34
	X-strong	18	4.50	.48	8	18.91
	XX-strong	18	4.50	.52	8	20.29
5	Standard	18	5.56	.40	8	20.22
	X-strong	18	5.56	.49	8	24.40
	XX-strong	18	5.56	.53	8	26.15
6	Standard	18	6.63	.43	8	26.13
	X-strong	18	6.63	.51	8	30.59
	XX-strong	18	6.63	.55	8	32.78
8	Standard	18	8.63	.50	8	39.85
	X-strong	18	8.63	.56	8	44.29
	XX-strong	18	8.63	.60	8	47.22

THREADED CAST IRON DRAIN PIPE

For Waste, Vent and Drainage Service

(Made to meet the requirements of Federal Specifications WW-P-356)

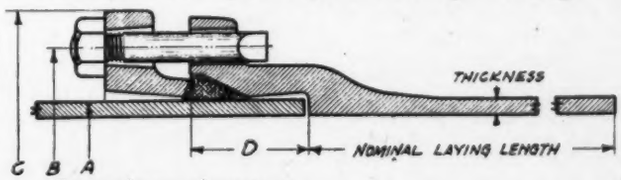
Size Inches	Nominal Length Feet	Outside Diameter Inches	Minimum Thickness Inches	Threads per Inch	Weight per Foot Pounds
3	12	3.50	.26	8	9.41
4	18	4.50	.29	8	13.75
5	18	5.56	.33	8	19.05
6	18	6.62	.38	8	26.22
8	18	8.62	.44	8	39.82

THE U. S. JOINT

The U. S. Joint embodies the more favorable features of certain other types of mechanical joints and was developed and patented by the United States Pipe and Foundry Company after considerable study and research. It is adaptable to both Super deLavaud Centrifugal Pipe, and to pit cast pipe and fittings and these may be interchanged one with another in the laying of a line without the need of an adapter. The accessories, which consist of follower ring, gaskets and bolts are all interchangeable.

It possesses the following salient advantages:

Write for "U. S. Joint Pipe and Fittings" Catalog.



1. **Ruggedness of parts.**
2. **High resistance to corrosion since all of the joint accessories are of the same material—cast iron.**
3. **Maximum joint deflection without leakage.**
4. **Great resistance to the flow of electric currents.**
5. **Ease of assembly—needs only one wrench.**
6. **Only one gasket per joint.**
7. **Excellent qualities as an expansion joint.**
8. **Tightness under high pressures of gas or water.**
9. **Connection to plain end existing pipe line without use of adapter.**

MAINTENANCE OF VALVES AND HYDRANTS

By CARL A. HECHMER*

Hyattsville, Md.

It is surprising, especially in small towns and villages, how little attention is given the maintenance of gate valves and fire hydrants on their water systems. The need of good engineering advice and design is recognized and is compulsory in almost every state. Practically every state health department has a law compelling the submission of plans for approval before a water system can be built. The question of good materials is also generally given the utmost consideration and the best valves and hydrants obtainable, in the judgment of those in charge, are purchased and put into the water system. In many instances they are promptly forgotten until an emergency arises and quick, sure operation is necessary. Unless valves and hydrants are given regular attention and properly maintained, the water works superintendent has no assurance that they will function properly. This fact applies to any make of valve or hydrant or to any other mechanical device or piece of machinery. Unfairly, the failure reflects on the designing engineer or the manufacturer of the material, and the local department is given a clean bill of health.

Valves

All valves on a water distribution system should be inspected once each year. This is the minimum requirement of the Fire Underwriters' Association. However, semi-annual inspection is advisable, if finances will allow it. Not only will the mechanical condition of the valve be assured, but valve boxes covered by paving material or earth will be located and reset ready for immediate operation in emergency. This is especially true in rural and suburban sections with a large percentage of unpaved streets. When a large leak occurs, excitement prevails and considerable time may be lost in locating a valve box. Occasionally a large stone or stones are found down in valve boxes and these conditions are revealed on inspection and removed. In case the valve has to be dug up, uncovering the valve, it is advisable to install new packing in the packing gland, which will prevent digging it up for repacking for a long time. Always repack a valve when it is uncovered for any repairs. Packing is cheap and easily installed while the valve is exposed. To dig up a valve just to stop a packing leak is an expensive operation. Inspection also locates valves which were carelessly or accidentally left closed. Any water distribution system is weakened by gate valves being closed when they should be open.

How a Valve Inspection Should Be Made

In addition to the box inspection, a valve inspection should proceed as follows: First set the valve key on the valve nut preparatory to turning the stem. Pour a small quantity of kerosene or diluted automobile crankcase drainings down the valve key stem. The oil will run down the key to the operating nut, thence to the valve stem and lubricate the valve stem against the packing gland. Finding its way into the packing gland, the packing will be softened and revived. Then operate the valve up and down several times, bringing the gate down into the groove hard each time and then opening the valve about one-quarter way. Valve troubles, preventing complete shutdown, are usually caused by the accumulation of sediment under the seat. Each time the gate is pushed down into the groove a small portion of this sediment is pushed out the sides. The high velocity of the water through the partly opened valve removes what is pushed out and the operation is repeated until the groove is sufficiently cleaned to allow the gate to seat properly. This procedure is especially recommended when valves fail to hold when attempting a shutdown. Of course, if the groove is filled with large stones or jointing material, the valve must be dug up and taken apart for repairs. The writer once operated a 16-inch valve up and down thirty times and secured a perfectly tight shutdown. The valve had not been operated for a long time, having been declared worn out, since it always allowed a large volume of water to pass with the gate turned down hard with levers on the key.

In operating the valve a check should be made of the number of turns on the stem. Generally, for the same size and make of valve, the number of turns to close or open the valve completely is the same, and a check can be made to see if the stem is bent, preventing the valve from completely closing or opening. Either condition should be corrected, as partly open valves weaken the system and, obviously, partly closed valves will not shut off the water.

If the valve stem can be turned around and around with no apparent effect on the gate, the stem is broken and must be repaired.

Geared valves, usually set in manholes, must be given special attention on inspection. The gears should be cleaned with a wire brush and greased with a light clinging grease. The stuffing box should, of course, be examined, and the by-pass valve should receive the same attention as the smaller valves on the distribution system.

Fire Hydrants

Proper care in the installation of a fire hydrant is necessary and makes maintenance less expensive. Proper drainage of the hydrant barrel after the main valve is closed is essential to prevent freezing of the hydrant in northern climates. The best method is to provide a bed of crushed stone or gravel around the bottom of the hydrant. The amount of stone necessary is dependent on the nature of the soil. In loose sandy soils a much smaller drainage bed can be provided than in a clay soil that absorbs water very slowly. A safe margin is to provide sufficient area to allow the drainage of an amount of water equal to twice the contents of the hydrant barrel. Connections are often made direct from the hydrant drain valve to the sewer. However, there are two serious objections, first, the cost and, second, the direct connection between a sewerage system and a domestic water supply, even though the possibility of contamination reaching the water in the mains is remote. Generally water mains are laid on one side of the street and sewers on the other. Hydrants are installed at the curb on the same side as the water mains to shorten the length of the lead. To connect each hydrant drain across the street to the sewer would prove much more expensive than providing a stone drainage bed.

Fire hydrants must be inspected at least twice each year, in the spring and fall. Four inspections annually should be made, if possible, and this number of inspections is advocated by the Fire Underwriters' Association. In high value districts, weekly inspections are often made during extremely cold weather. Arrangements should be made between the water department, the fire department and any other possible users of hydrants to report to the water department immediately after using a hydrant during freezing weather and an immediate inspection made to insure the good condition of the hydrant. Use of hydrants by private individuals or contractors should be allowed only by special permit, and the daily charge made high enough to permit daily inspection during freezing weather. During mild weather the inspection charge can be reduced, as weekly inspections are sufficient.

Valuable data may be secured by the fire hydrant inspection by measuring the static pressure, the residual pressure with one nozzle open, and the flow of water from the hydrant. [See artitcle on making hydrant flow tests (Wilson) elsewhere in this issue.—Ed.] Weak points on the distribution system can thus be determined and improvements due to new installation readily noted. System weakness due to unknown closed valves is also discovered and can be corrected.

Procedure for Making a Hydrant Inspection

The following procedure is suggested for making a hydrant inspection:

First make a physical examination of the hydrant, noting the condition of the operating nut, the nozzle caps and chains, and the general appearance of the hydrant. Then listen for leakage with an aquaphone placed on the operating nut. Then with the nozzle caps on tight open the hydrant valve. If static pressure readings are to be taken, replace one of the nozzle caps with one connected to a pressure gauge. Note if all the nozzles are tight in the hydrant and whether the drain valve has closed properly. If the drain valve has not closed, water will appear around the barrel of the hydrant on the outside. Then close the main hydrant valve and take off one of the nozzle caps. Observe the rate of drainage of the barrel to determine whether any obstruc-

*Engineer of Distribution, Washington Sanitary District.

tion has entered the drain valve. To clean the drain valve replace the nozzle cap and crack the main valve. As it requires about three full turns open on the main valve to completely close the drain valve on most makes of fire hydrants, the latter is still open on two turns. The full pressure of the water in the hydrant generally will push out any obstruction in the drain hole and the jet effect of the water through the hole will cut away the stone or earth which has packed around the outside. This simple remedy will eliminate the necessity of digging up the hydrant, in most cases, to correct drainage troubles.

With one nozzle cap off, open the hydrant and thoroughly flush out the water in the lead. At this time the observation of residual pressure and rate of flow should be made. Then close down the hydrant slowly. If the hydrant fails to close off entirely, the trouble is probably being caused by an obstruction under the main valve. Do not put extra leverage on the hydrant wrench, but open the hydrant up again and then close it, repeating the operation several times. Do not attempt to close down beyond the point where the obstruction prevents the main valve from seating properly, as the obstruction will become embedded in the main valve and connot be flushed off, or the valve seat will be damaged. Both valve and valve seat are damaged by attempts to force closing against obstructions. Foreign matter can generally be dislodged by flushing and it is then not necessary to dismantle the hydrant.

After the hydrant is closed and the rate of drainage checked, the stem should be oiled and the nozzles greased with a graphite grease. This kind of grease will not wash off and it prevents the nozzle caps from sticking.

Inspection Records

Record of the inspection should be kept on a field sheet. The location of the hydrants to be inspected can be entered on the sheet in the office. These will allow correct routing and prevent skipping any hydrants. The information on the field inspection sheets can then be transferred to a permanent record card in the office. A card should be in the file for each hydrant, stating the size, make of hydrant, and information regarding pressure at the hydrant. The date of each inspection should be entered on the card together with the observed pressures and rate of flow. Necessary repairs and their costs can also be recorded on the card and a history of each individual hydrant is easily obtained.

For quick reference the following is suggested: Use a map of the water system mounted on wall board with a push pin to denote the location of each hydrant. The color of the pin can show the condition of the hydrant as reported daily by the hydrant inspectors and the repair foreman. Use a blue pin for a hydrant in good condition, a black pin for a hydrant in need of minor repairs but not out of service, and a red pin for a hydrant out of service. Then when an inspector reports a hydrant out of service it is possible to tell at a glance whether the hydrants around it are in good condition. If several makes of hydrants are in use, it is an advantage to know the make of hydrant before sending out a repair gang so the proper parts can be carried along. By using a small round colored disc under each push pin it is possible to determine at a glance the make of each hydrant, a different color being used for each make of hydrant.

TEMPERATURE CONVERSION TABLE

C.		F.	C.		F.	C.		F.	C.		F.
—40.0	*—40*	—40	— 3.89	*25*	77.0	12.8	*55*	131.0	28.9	*84*	183.2
—34.4	*—30*	—22	— 3.33	*26*	78.8	13.3	*56*	132.8	29.4	*85*	185.0
—28.9	*—20*	— 4	— 2.78	*27*	80.6	13.9	*57*	134.6	30.0	*86*	186.8
—23.3	*—10*	14	— 2.22	*28*	82.4	14.4	*58*	136.4	30.6	*87*	188.6
—17.8	*0*	32	— 1.67	*29*	84.2	15.0	*59*	138.2	31.1	*88*	190.4
—17.2	*1*	33.8	— 1.11	*30*	86.0	15.6	*60*	140.0	31.7	*89*	192.2
—16.7	*2*	35.6	— 0.56	*31*	87.8	16.1	*61*	141.8	32.2	*90*	194.0
—16.1	*3*	37.4	0	*32*	89.6	16.7	*62*	143.6	32.8	*91*	195.8
—15.6	*4*	39.2	0.56	*33*	91.4	17.2	*63*	145.4	33.3	*92*	197.6
—15.0	*5*	41.0	1.11	*34*	93.2	17.8	*64*	147.2	33.9	*93*	199.4
—14.4	*6*	42.8	1.67	*35*	95.0	18.3	*65*	149.0	34.4	*94*	201.2
—13.9	*7*	44.6	2.22	*36*	96.8	18.9	*66*	150.8	35.0	*95*	203.0
—13.3	*8*	46.4	2.78	*37*	98.6	19.4	*67*	152.6	35.6	*96*	204.8
—12.8	*9*	48.2	3.33	*38*	100.4	20.0	*68*	154.4	36.1	*97*	206.6
—12.2	*10*	50.0	3.89	*39*	102.2	20.6	*69*	156.2	36.7	*98*	208.4
—11.7	*11*	51.8	4.44	*40*	104.0	21.1	*70*	158.0	37.2	*99*	210.2
—11.1	*12*	53.6	5.00	*41*	105.8	21.7	*71*	159.8	37.8	*100*	212.0
—10.6	*13*	55.4	5.56	*42*	107.6	22.2	*72*	161.6	43	*110*	230
—10.0	*14*	57.2	6.11	*43*	109.4	22.8	*73*	163.4	49	*120*	248
— 9.44	*15*	59.0	6.67	*44*	111.2	23.3	*74*	165.2	54	*130*	264
— 8.89	*16*	60.8	7.22	*45*	113.0	23.9	*75*	167.0	60	*140*	284
— 8.33	*17*	62.6	7.78	*46*	114.8	24.4	*76*	168.8	66	*150*	302
— 7.78	*18*	64.4	8.33	*47*	116.6	25.0	*77*	170.6	71	*160*	320
— 7.22	*19*	66.2	8.89	*48*	118.4	25.6	*78*	172.4	77	*170*	338
— 6.67	*20*	68.0	9.44	*49*	120.2	26.1	*79*	174.2	82	*180*	356
— 6.11	*21*	69.8	10.0	*50*	122.0	26.7	*80*	176.0	88	*190*	374
— 5.56	*22*	71.6	10.6	*51*	123.8	27.2	*81*	177.8	93	*200*	392
— 5.00	*23*	73.4	11.1	*52*	125.6	27.8	*82*	179.6	99	*210*	410
— 4.44	*24*	75.2	11.7	*53*	127.4	28.3	*83*	181.4	100	*212*	413
			12.2	*54*	129.2						

Example 1. 42° Fahrenheit to be converted to Centigrade: Find 42 in the center column (italic figures) and read 5.56° C. to the left.

Example 2. 42° Centigrade to be converted to Fahrenheit: Find 42 in the center column (italic figures) and read 107.6° F to the right.

(From the Data Section of Electro Bleaching Gas Co.'s brochure—"Liquid Chlorine.")

CARSON-CADILLAC CORPORATION

BIRMINGHAM, ALABAMA

PIPE JOINTS, LEAK CLAMPS, BOLTS AND PIPE FITTINGS

Segmental Joint

Leak Clamp

CARSON type MECHANICAL JOINTS for cast iron pipe are furnished by leading cast iron pipe companies, or may be purchased direct from us in sizes 2" to 60" inclusive. The gland grips the outside of the bell and compresses a ring gasket to make a tight but flexible joint that allows expansion and contraction.

CARSON LEAK CLAMPS effectively stop leaks in cast iron sewerage, gas or water lines because they automatically fit themselves to the bell joint. They are adjustable—

1. To fit variations in outside bell circumference.
2. To compress gasket uniformly regardless of variations.
3. To make snug fit around spigot, regardless of variations in spigot's diameter.

CARSON CLAMPS are furnished in sizes 4" to 48", inclusive.

CARSON-CADILLAC BOLTS, made of charcoal cast iron, are marketed under the trade names of "C-60 Bolts" and "C-57 Bolts." The difference between the two is in physical properties as follows:

C-60 Charcoal Cast Iron

(containing 1% copper)

Ultimate Tensile Strength	70,000 to 75,000#/sq. in.
Yield Point	50,000 to 55,000#/sq. in.
Elongation	9% in 2 inches*

*(A.S.T.M. Test Bar)

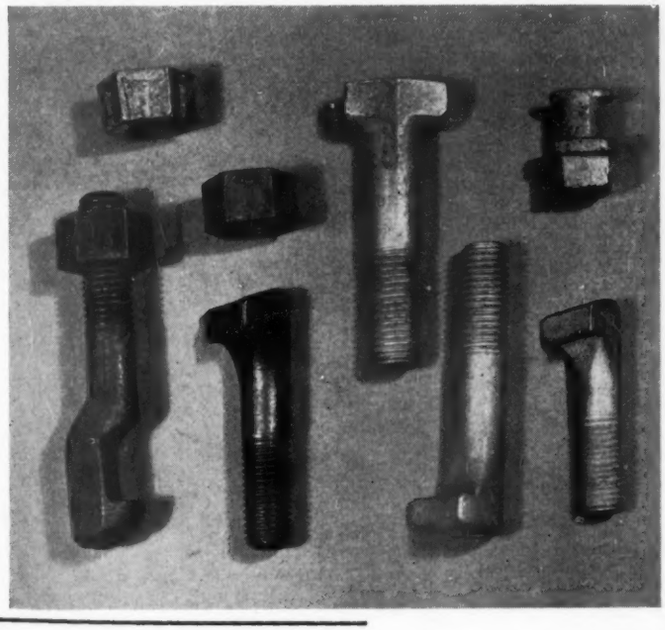
C-57 Charcoal Cast Iron

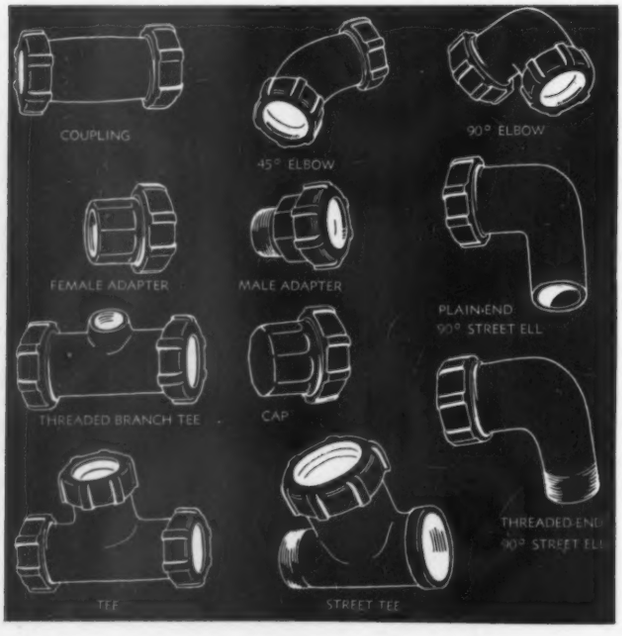
(containing 2% copper)

Minimum Ultimate Strength	60,000#/sq. in.
Minimum Yield Point	40,000#/sq. in.
Elongation	14% minimum in 2 in.*

*(A.S.T.M. Test Bar)

C-60 or C-57 bolts can be furnished in all standard sizes and with any shaped head desired—round, square, T-head, V-head and so forth. These bolts and nuts have unusual resistance to corrosion under all conditions.





CARSON charcoal cast iron Fittings for Plain-end Pipe are for working pressures up to 500 pounds per square inch and are furnished in sizes of ¾", 1", 1¼", 1½" and 2". They are easy to use, make a tight but flexible joint that allows expansion and contraction, and are very economical because they cost less. They are rugged and strong and cen be *re-used* over and over.

These fittings are installed by loosening the screwed gland (do not take it off), then inserting the pipe and tightening the gland with a wrench.

Gaskets furnished with these Fittings are suitable for use with compressed air, hot or cold water, steam, oil, manufactured or natural gas, acid mine water, oil refinery piping, gathering lines in oil field, as well as sewerage systems, etc.

FOUNDRIES AT CADILLAC, MICHIGAN

WELL CONSTRUCTION*

Some Notes and Experiences

By J. A. CARR

Superintendent, Water Department, Ridgewood, N. J.

In presenting this paper on well construction, let me say that I do not pretend to be an expert in this line. However, based on my own experiences, I shall attempt to bring to your attention a few points from the user's or purchaser's angle which may be of value to some.

My remarks will be confined to the drilling of wells in rock, that being the type of well with which I am most familiar.

The most important points in the construction of a new well seem to be the following:

1. Full and complete specifications and a bid sheet permitting a fair comparison of prices.
2. The selection of a responsible contractor.
3. A full-size hole, which is kept plumb.
4. Proper sealing.
5. Proper and complete testing.

Specifications and Bid Comparisons

It would seem as if the preparation of specifications for drilling a hole in the ground should be a simple matter. In my opinion it is not as simple as it first appears. There are several points both in the specifications and in the bid sheet which may cause difficulty in deciding on the low bidder and create misunderstanding in making payments. These points should be clearly set forth in fairness to both the contractor and the purchaser.

We, in Ridgewood, do not contract for a flat sum to a fixed depth, but call for bids by the foot. For instance, our bid sheet reads as follows:

Item 1. For drilling, furnishing, setting and sealing, both a ..... inch and a ..... inch casing from the surface of the ground to rock, as specified for $..... per lineal foot.

Item 2. For drilling a ..... inch well from the bottom of the casing to a point 150 feet deep for $..... per lineal foot.

Item 3. For drilling, etc., ... from a point 150 feet deep to a point 250 feet deep for $..... per lineal foot.

Item 4. For drilling, etc., ... from a point 250 feet deep to a point 500 feet deep, etc.

Usually the most expensive portion of the well is that portion which is cased down to and into rock. The depth into rock to which the casing will be carried cannot always be decided in advance. So, in order that all bids may be considered on an equal basis, the following statement is made in the specifications: "For the purpose of comparing bids, the distance from ground surface to rock will be considered to be ..... feet." The distance mentioned is the approximate depth we believe the rock to be.

Our specifications provide that we may stop drilling at any depth. Again, so that bids may be comparable, we state in our specifications: "While the contractor's bid is based upon a maximum depth of 500 feet, it is here distinctly understood that drilling may be stopped by the Engineer at any depth. It is guaranteed, however, that the contractor shall be paid for at least 200 feet of drilled well."

We provide that the well shall be tested once by, and at the expense of, the contractor. Furthermore, that more than one test may be required. In this precautionary specification, any uncertainty in bidding as to additional tests will be removed. The specified amount to be paid to the contractor for such additional tests is set up on an hourly basis.

Selection of Contractor

Next after the receipt of bids is the selection of a "skilled and experienced" contractor. This definition is taken to cover those who are not only responsible financially but, more important, those who know how and have the equipment to do a first class job. And, in addition, the desire to do it.

The improper care and use of drilling tools and improper handling of casings may result in defective wells, thereby causing much immediate or future trouble and expense.

There should be absolute insistence that the contractor's representative on the job, who is usually the rig operator, keep proper records and turn over to the purchaser full and complete information as to what is being done, and what is happening as the work progresses. Samples of drillings at various depths should be preserved.

Unfortunately, there are still some drillers who wish their operations to be considered secret. They should be impressed with the fact that there are two parties, the owner and the contractor, who should know all there is to know about the hole. Full and accurate records are most essential for the proper future maintenance and operation of the well.

What Size Hole?

The hole should be started at that size sufficient to permit as many reductions in diameter as may prove necessary and still have ample diameter for pump installation and to permit future work or alterations.

We recently had occasion to insert a 10-inch casing in a well that had already been reduced from 16 inches to 12 inches. Had the hole been started smaller, it might have been necessary to abandon it. It is poor economy to start drilling with a small hole.

The well should be plumbed and gauged at frequent intervals during drilling, in order that the purchaser may be assured a straight plumb hole of the required size. Watching the cable to see that it hangs in the center of hole is a rough check for plumb. The bits should be frequently checked to see that they are the full diameter required.

While a hole slightly out of plumb, so long as it is a straight hole, does not interfere to any great extent with a pump setting, a zigsag or corkscrew hole can cause no end of trouble and expense. This fact was vividly demonstrated to us recently when we inserted a 10-inch inner casing in an old 12-inch well. The casing above rock was out of plumb and there was a constriction in diameter of the rock hole which it became necessary to correct before the 10-inch casing could be entered.

Sealing

I believe that there is only one sure and permanent way of sealing a rock hole to shut off surface or top ground water. That is by double casing, in which the annular space between the two is grouted with neat cement.

On new holes we require the outer casing to be driven to the rock. The drilling is then continued the same size as the outer casing to a depth beyond all soft or broken formation, which is equal to the length of the string of tools. The hole is then filled with sand to a point where the inner casing is to set.

The balance of the hole is then partially filled with neat cement. A cast iron plate is welded over the bottom end of the inner casing and it is lowered and pushed into the cement to the required depth. This gives the inner casing a piston action forcing the cement around the bottom of the casing, and up into annular space between the two casings. The balance of the space is filled with cement slurry to the top. After the mortar has set for several days the cast iron plate is knocked out, the sand bailed out of the hole, and drilling continued into rock.

The purpose of the sand is to permit the string of tools to hand out of the casing when drilling is resumed, and thus avoid jarring and cracking the cement.

When inserting an inner casing in old wells, the hole is bridged at the required depth and the same procedure followed.

In placing the cement in the well considerable care is necessary, because if the cement is put in dry it has a tendency to bridge before reaching the bottom and not entirely fill the annular space. We have found it most satisfactory to mix the cement with water to the consistency of heavy cream and pour it in. Whether or not the space is entirely filled can be roughly checked by computing the volume of slurry required.

If the cement is placed dry, a small pipe carrying air from a compressor should be lowered to the required depth and gradually withdrawn as the hole fills. By this means the bubbling air prevents bridging of the cement.

*From WATER WORKS AND SEWERAGE.

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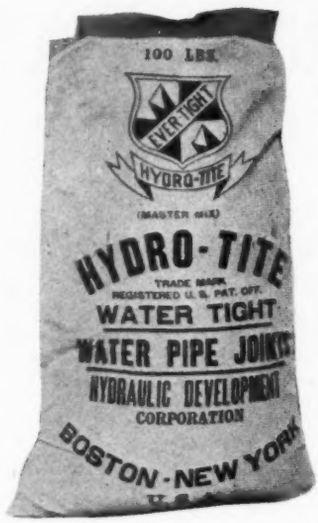
For many years some of the best trained chemical scientists, besides the great laboratories of the Massachusetts Institute of Technology, have played a large part in making Hydro-Tite the leader in its field. Constant inspection, alert supervision and much research make the uniformity of Hydro-Tite what it is. This makes possible our continued use of the slogan—"more than 25 years without a failure".

HYDRO-TITE is a black powder scientifically compounded under skillful and careful supervision. It is composed entirely of selected inert minerals. When melted and allowed to cool, Hydro-Tite becomes a strong, tough, metallic mass. It has a high compressive strength of 6,000 lbs. per square inch and a tensile strength of over 650 lbs. per square inch. While Hydro-Tite has been used for a number of purposes, such as repairing leaks in reservoirs, breaks in castings, etc., its use is confined almost entirely to the making of cast-iron bell and spigot pipe joints.

SELF-CAULKING—Hydro-Tite melts over a small fire and nothing is added to make it become liquid. When poured into a joint it immediately solidifies upon contact with the metal and bonds to both the surfaces of the bell and the spigot for the entire depth of the joint. Hydro-Tite requires no caulking and after pouring a joint, water pressure may be immediately applied.

APPROVED BY — Hydro-Tite is approved and used by leading engineers, municipal water works, water companies, railroads, mines and industrial plants throughout this country and many others. It is also approved by the Associated Factory Mutual Insurance Companies and will be found listed on page 5, their "Rules for Laying Cast-Iron Pipe," issued June, 1929.



PACKED AND SHIPPED—Hydro-Tite is packed and shipped in 100-lb. heavy burlap bags. While age and dampness do not affect the quality of Hydro-Tite, it will handle much easier if dry. Each bag contains a specially treated moisture-proof liner which keeps the Hydro-Tite dry even though stored in a damp place or transported in the rain.

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The use of Hydro-Tite is standard practice in many water companies and water works throughout every section of this country and Canada. It is also used in various Central and South American countries and frequent shipments are made to points throughout the civilized world.

It is a significant fact that a good proportion of the private water companies in the United States and Canada are confirmed Hydro-Tite users. Many discriminating water works engineers, seeking the best by testing various jointing materials, select Hydro-Tite for joints on cast-iron pipe lines of all sizes.

We will be glad to refer you to some officials of large and small water systems located near you who are using Hydro-Tite. Your inquiry will receive prompt attention and will incur no obligation.

OVER 25 YEARS IN SERVICE WITHOUT A SINGLE FAILURE

HYDRANT DISCHARGE MEASUREMENTS

Practical Methods of Making Measurements; Computing and Applying Results

By P. S. WILSON*
Water Works Consultant, Glen Ridge, N. J.

The measurement of the discharge or flow from fire hydrants is a common procedure for engineers engaged in testing the fire fighting capacity of a water system. The fact is frequently overlooked that such measurements may also be very usefully applied to many other vital problems with which the operator of a water supply system is regularly confronted. It is likewise not always realized that this work may be performed with but a small expense for equipment and without the need for special technical training.

Actual measurements of the flows taking place in a water distribution system may furnish extremely valuable information to the water works operators. A water distribution system is different from most of the equipment with which other business is conducted. It is buried underground and is not subject to ready inspection. The greater portion of it has not been seen for a generation or more. Its present operator has never seen most of it and almost all he knows of it is what he has been told second or third hand or what he learns from maps and records which are in many cases woefully deficient. What information he does obtain about his system is mostly history,—what it was when it was last seen, years before, not what it is now. It is on account of these conditions that actual tests and measurements are of such great value. One can authorize for a long time as to whether a certain valve is open or shut and one may even operate the valve one way or another and still not know much more than before. But if the water in proper quantity flows through that valve and evidences itself on the other side, then the question is settled and there is no more possibility for argument.

There are two principal methods of making field measurements of the flows in water distribution systems. One of these is by means of the Pitot orifice tube inserted through a corporation cock in the side of a main. Such measurements when properly applied are of inestimable value. However, a method, of making tests, which is more readily available to the average operator, involves the measurement of hydrant discharges and less time, expense, and equipment are necessary therefore. Measurements so made are not, of course, a complete substitute for Pitot measurements in the pipes, but in many cases they may suffice in themselves to answer the questions at hand. Even if they do not, they always form a valuable guide and adjunct in the making of further and more elaborate tests, if these are later found necessary.

Methods of Measuring Hydrant Discharge

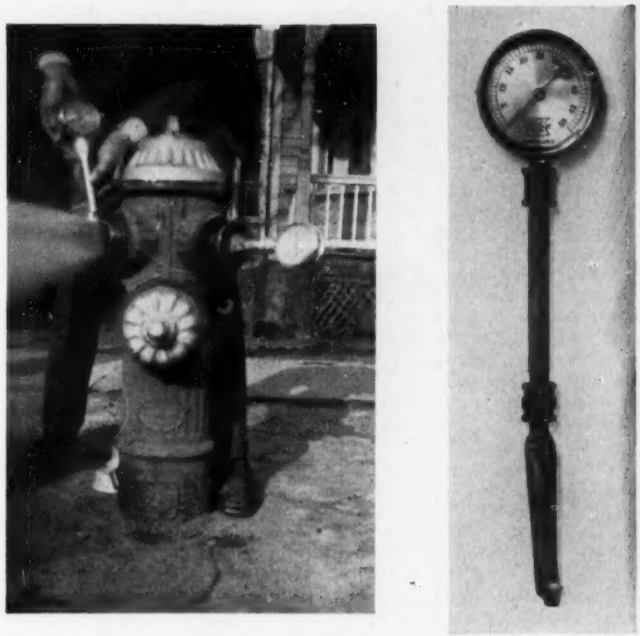
Measurements of the discharge from an ordinary fire hydrant with sufficient accuracy for most practical purposes is not difficult. By the exercise of care and good judgment, results may be obtained within fairly close limits of accuracy. Rough and ready methods are for the most part amply sufficient, since, for the purposes usually involved, the conclusions arrived at would not be changed by a variation of five or ten per cent one way or the other in the test results. Some of the rather approximate methods to be given must be judged with this fact in mind.

The discharge from a hydrant nozzle is determined from the size or cross sectional area of the emerging stream and from the average velocity of that stream. From these two figures the discharge may readily be computed or may be directly read from tables or diagrams such as those appended to this article.

Measuring Nozzle Diameter—Observation of flow from hydrant nozzles shows that it completely fills the nozzle, as a general rule. Therefore, a simple measurement of the internal diameter of the hydrant nozzle serves to make known the diameter of the stream of water. The entrance to the nozzle from within the barrel may occasionally (particularly in some old styles of hydrants, and hydrants with independently gated nozzles) be sharp enough to cause the emerging stream to be contracted slightly below the size of the nozzle and if such an effect is noted it should be allowed for in the diameter used. The internal diameter of each nozzle used should be carefully measured to the nearest one-sixteenth of an inch. An ordinary carpenter's rule is satisfactory for this purpose.

Determining Stream Velocity—The average velocity of the emerging stream of water may be determined in either of two ways. The most common method is by the use of a hydrant Pitot tube which may be inserted into the stream and which transforms the velocity head of the stream into the equivalent pressure head and registers it on an attached pressure gage. This instrument is here pictured. It consists of a hollow blade or "cut-water," shaped so that it may be thrust into the stream without unduly deflecting it. At the end of the blade is a small opening which points directly against the flowing water. The force of the stream striking into this opening creates a pressure in it which is transmitted through the hollow blade and handle to the pressure gage. The gage is an ordinary good pressure gage, except that it should be graduated to read more closely than most gages. The gage most frequently used is graduated every pound and only reads up to about fifty pounds per square inch pressure. It must be a good grade of gage to maintain its accuracy with such close reading. For some purposes it is of value to have a very low pressure gage graduated to half pounds. Sometimes the Pitot tube and the gage are held in place in the stream by a device which clamps over the outside of the nozzle. This device is not ordinarily considered necessary, however, and its use results in greater damage to the Pitot tube if struck by a stone or other object carried by the water. The edges of the blade and the small orifice into it must be kept sharp and symmetrically shaped or the accuracy of the instrument will be seriously affected.

In use, the Pitot tube is held in the stream and the pressure read while the small orifice is held at the center of the stream and pointing directly against the flow. Occasionally on large nozzles it is advisable to take a rough average of the pressures across the stream at different points horizontally and vertically. In most cases the pressure at the center will be found to be practically the average. In no case should the pressure very near the edge (within about one-fourth inch) be considered.



Two Methods of Determining Velocity of Nozzle Discharge. (Gage on Pitot Tube Held in Stream and Gage, Indicating Barrel Pressure, Show Practically Same Readings)
Hydrant Pitot Tube with Gage at Right

*Now Technical Asst. Secy., A.W.W.A.

The other method of determining the velocity of the stream, and one which has been occasionally found more convenient by the writer, consists merely in placing on one of the hydrant nozzles a cap having an ordinary pressure gage tapped into it then allow the discharge to take place through the other nozzles. Due to the free discharge from the nozzles, practically all of the pressure head remaining in the barrel during the flow is transformed into velocity head in the jets. Since that is practically the only source of velocity head in the jets, the ordinary pressure gage indicating the pressure in the barrel will read substantially the same as a gage on a Pitot tube held in a jet. This fact may be readily confirmed by trial. In this way the discharge of a hydrant may be measured with fair accuracy, without the Pitot tube, merely by the use of a pressure gage, the gage reading being used to compute the discharge in the same manner as if it were a Pitot tube reading. The same type of gage should be used for this method as described above for the Pitot tube. Any pressure gage may be used, however, the accuracy of the results depending upon the accuracy of the gage and the closeness of the graduations and readings.

An accompanying illustration shows a Pitot tube with gage being held in the stream from one hydrant nozzle while a pressure gage on the other nozzle is at the same time indicating the pressure in the barrel. This illustrates the two methods of determining the velocity head of the stream. Unfortunately the photograph does not make it possible to see what the gages are reading; actually they show the same—18 pounds per square inch. In using the Pitot at low velocities, where a quarter pound makes an appreciable difference, the instrument should be held horizontally so that the pressure gage will be at the same elevation as the nozzle.

With the same accuracy of gage reading the only inaccuracies in the second method as compared with the use of the Pitot tube are in the fact that there is a slight loss of head in entering and flowing through the nozzle and in the assumption that the velocity head in the barrel at the point of pressure reading is zero. This latter assumption is justified because the velocity in the barrel is low compared to that in the jet and the pressure reading is taken opposite or above the other nozzles which are discharging. In any case, as before mentioned, trial will show that the results are in general substantially the same for both methods. If the hydrant Pitot tube is at hand, its use is best and most convenient; the availability of the other method, however, should always be borne in mind.

The pressure gage on one nozzle, of course, prevents the use of that nozzle for the discharge of water. This is not always a disadvantage, however, particularly when the hydrant is equipped with a steamer nozzle which may be used for attaching the gage.

A fact which may readily be perceived from the foregoing is that, when measuring the velocity with a Pitot tube, readings need only be taken (except as a check) in one of several nozzles discharging simultaneously because readings in all of the nozzle streams should be practically alike.

Computation of the Flow

By the measurement of the nozzle diameter we now have obtained the diameter of the stream of water, and from the pressure gage reading we have obtained a figure which bears a known relation to the velocity of the stream. The formula for the discharge may now be readily derived from the fact that:

Discharge = (area of stream) × (average velocity)

If d = the internal diameter of the hydrant nozzle in inches, then, using the formula for the area of a circle, the area of the stream is $\frac{3.14xd^2}{4}$ square inches. For convenience in computing, this is divided by 144—the resulting formula being $0.00545xd^2$ to obtain the area of the stream in square feet.

The pressure gage reading, in pounds per square inch (p) is changed to feet of water head by multiplying it by 2.31. A fundamental hydraulic formula states that the velocity of the stream of water is equal to the square root of the pressure head multiplied by the square root of two times the acceleration of a falling body, due to gravity. This latter (g) is a constant and is equal to 32.2 in foot and second units. Therefore:

(a) Velocity of the stream in feet per second =
$$\sqrt{2.31} \times p \times \sqrt{2 \times 32.2} = 12.2 \times \sqrt{p}$$

(b) Discharge in cubic feet per second =
$$0.00545 \times d^2 \times 12.2 \times \sqrt{p} = 0.0665 \times d^2 \times \sqrt{p}$$

(c) Discharge in gallons per minute =
$$29.9 \times d^2 \times \sqrt{p}$$

The velocity of the stream of water as determined by either of the two methods described does not take into account the very low velocity of the stream around the edges where it is held back by its contact (friction) with the nozzle. To make allowance for this, as well as to allow for a possible slight contraction of the jet, it is necessary to make use of a coefficient in computing the results. This coefficient has been determined experimentally by checking hydrant flow measurements against other and more accurate means of metering the flow. The coefficient should, theoretically, be different for different hydrants, but it is sufficiently accurate for the purposes and means of measurement under discussion to use an average figure which has been found by experiment to be about correct for most cases. The figure most generally used is 0.90 and thus the formula derived above is modified as follows:

(d) Discharge in gallons per minute =
$$0.90 \times 29.9 \times d^2 \times \sqrt{p} = 26.9 \times d^2 \times \sqrt{p}$$

For convenience the 26.9 may be rounded off to an even 27 without introducing an error of importance, resulting in the completed formula:

(e) Discharge in gallons per minute =
$$27 \times d^2 \times \sqrt{p}$$

in which d = diameter of nozzle in inches and, p = gage reading in lbs. per sq. inch.

The Advantage of Tables and Charts

From this formula tables may be constructed in which the discharge is given for each combination of diameter of nozzle and Pitot pressure head and from which the result of the measurement may therefore be read directly without computation. A specimen is shown in Table 1. The discharges in this table are given to the nearest ten gallons per minute. Tables may be made up very conveniently to fit in field note books. For special purposes they may be abbreviated or enlarged either in range or in closeness of reading.

Another method of handling the formula is by the use of diagrams. A particularly convenient form for such a diagram, which the author has never seen in use elsewhere, accompanies this article. In this diagram measurements horizontally from the origin or zero are proportional to the square root of the Pitot pressure head, $\sqrt{p}$. Measurements vertically are proportional to the discharge of the hydrant nozzle in gallons per minute. An inclined straight line passing through the origin then represents each value of the nozzle diameter, (*d*). A heavy line is drawn for each size of nozzle in use using the theoretically correct value of *d*,—for example 2½ inches for an ordinary hose nozzle. Light lines are then drawn on the diagram below and above the first ones representing ⅛-inch undersize and oversize of each nozzle. From these three lines values for each 1/16 to ¼-inch under and over the nominal sizes may readily be read on the

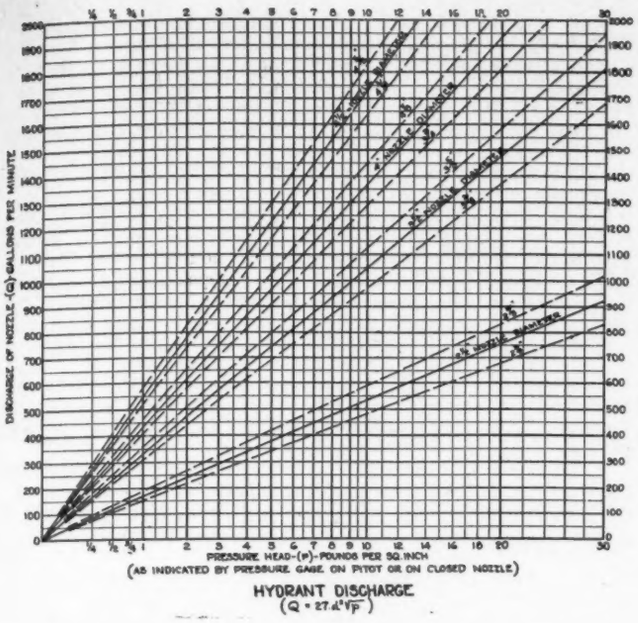
TABLE 1—HYDRANT DISCHARGE*

Gallons per minute = $27 d^2 \sqrt{p}$

Gage Reading—Hoze nozzle diameter in inches [d]

p	2 7/8	2 15/16	3	2½	2 9/16	2 5/8
¼	70	80	80	80	90	90
½	100	110	110	120	120	130
¾	120	130	140	150	150	160
1	140	150	160	170	180	190
1¼	160	170	180	190	200	210
1½	180	190	200	210	220	230
1¾	190	200	210	220	230	250
2	200	210	230	240	250	260
2½	230	240	250	270	280	290
3	250	260	280	290	310	320
3½	270	280	300	320	330	350
4	290	300	320	340	350	370
4½	310	320	340	360	380	390
5	320	340	360	380	400	420
5½	340	360	380	400	420	440
6	350	370	390	410	430	460
6½	370	390	410	430	450	470
7	380	400	420	450	470	490
7½	400	420	440	460	490	510
8	410	430	450	480	500	530
8½	420	440	470	490	520	540
9	430	460	480	510	530	560
9½	440	470	490	520	550	570
10	460	480	510	530	560	590
11	480	510	530	560	590	620
12	500	530	560	590	610	650
13	520	550	580	610	640	670
14	540	570	600	630	660	700
15	560	590	620	650	690	720
16	580	610	640	670	710	740
17	600	630	660	700	730	770
18	610	650	680	720	750	790
19	630	660	700	700	770	810
20	640	680	720	750	790	830
22	680	710	750	790	830	870
24	710	750	790	830	870	910
26	740	780	820	860	900	950
28	760	810	850	890	940	980
30	790	830	880	920	970	1020

*Discharges shown to nearest 10 gals. per min.


DISCHARGE OF NOZZLE-(Q)-GALLONS PER MINUTE
PRESSURE HEAD-(P)-POUNDS PER SQ. INCH
(AS INDICATED BY PRESSURE GAGE ON PITOT OR ON CLOSED NOZZLE)
HYDRANT DISCHARGE
(Q = 27.4d²√p)

Hydrant Discharge Diagram. (Courtesy, Community Water Service Co.; this Chart Having Been Prepared by the Author While Connected with the Company)

diagram. This covers the usual variation of the nozzles. It is to be noted that the horizontal distances on the diagram are not directly proportional to the pressures but to the square roots of the pressures. This results in uneven spacing of the figures, but by so constructing the diagram the lines representing the nozzle diameters may be drawn straight, whereas otherwise they would be curved. The uneven spacing of the pressure lines makes accurate interpolation difficult, and therefore enough lines are drawn on the diagram to make this unnecessary. Having made a discharge measurement this diagram is used as follows: Pick the vertical line representing the Pitot pressure reading, follow it up or down to where it crosses the line representing the actual measured internal diameter of the nozzle, estimating where that line would be if the correct one is not on the diagram. Then follow the horizontal lines to right or left and read the discharge on the vertical scale.

A Few Comments

A careful study of the formula and the tables and diagrams leads to a number of important observations on the carrying on of this work. When the Pitot pressure reading is low, a slight difference in the reading will result in a very large percentage difference in the result, whereas at higher pressures a half pound or even a pound does not make much difference. For instance the difference between 1 and 2 pounds per square inch makes about 40 per cent difference in the discharge while the difference between 10 and 11 pounds per square inch makes only about 5 per cent difference. This fact is the reason for making the pressure differences in the table and diagram smaller in the lower range. It also indicates the necessity for making very careful Pitot pressure determinations in the field, particularly at low pressures. Gages should be closely graduated as before mentioned and should have at least three inch dials. On particular work they should be calibrated with a dead weight tester before and after using and corrections applied to the readings if necessary. Gages should be handled gently and with care so as to maintain their accuracy. Since they will probably not read as high as the static pressure in the mains, care should be taken when taking pressures on a closed nozzle not to subject them to too much pressure. Other gages must, of course, be provided for taking the direct main pressures.

Emphasis must be placed on the necessity for keeping the connections between the Pitot blade and the pressure gage absolutely tight. A very slight leak, in fact only a drip which in the general splashing may not be noticed, is sufficient to make the reading considerably in error. The connections should be made up tightly with wrenches and should not be loosened in order to turn the gage into a more convenient position.

It will be noted that a 1/16-inch difference in the diameter of the nozzle makes a much greater percentage difference at high discharges than at low ones. This is the opposite from the effect of the pressures. In spite of this it will usually result in greater accuracy to use as few and as small nozzles as possible in a measurement. The use of steamer nozzles is advised only on work where approximate results would be satisfactory. Further experiments may show that a slightly different coefficient should be used in computing the discharge of the larger sizes of nozzles.

Fire Flow Tests

The making of fire flow tests is the most obvious use to which hydrant flow measurements may be put. Such tests consist in the determination of what amount of water is available at a given hydrant, or at a given group of hydrants, for use by the fire department. This test is the one usually made by the engineers of the National Board of Fire Underwriters in rating a system for fire protection. So much has been written on such tests that they need be only mentioned here. Simultaneous readings are taken on as many hydrants in a group as are needed in order to develop the capacity of the system. At the same time a record is kept at an adjacent hydrant (not discharging), of the residual pressure. From a set of such readings the discharge capacity of the system at that point with any residual pressure may be known.

The residual pressure mentioned above is the pressure remaining in the mains during the time that a flow test is taking place. This pressure is determined by the readings of a pressure gage attached to a hydrant which is *not* discharging but which is located close by and, if possible, on the side opposite to the direction from which the flow is coming. The actual capacity of the distribution system at a given point is usually considered to be the discharge with the residual pressure drawn down to some stated figure. By this method the results of flow tests at different points and on different systems are made comparable. When fire engine pumpers are to be used then the maximum capacity of the system may be considered as the discharge with the residual pressure drawn down to 20 lbs. per sq. in. If reliance is placed on direct hydrant pressure for the hose streams then the residual pressure can not be drawn down nearly so low and the maximum capacity of the system at such higher residual pressures will be less. Sometimes the capacity of a system is referred to as the discharge with a drop in pressure of 20 lbs. per sq. in., in other words, with a residual pressure 20 lbs. per sq. in. less than the original pressure before the hydrants were opened. This will usually be a very different figure from the capacity at 20 lbs. per sq. in. minimum residual pressure.

It is usually difficult or impossible to make a flow measurement at exactly the rate of discharge which will result in the residual pressure desired. It is customary, therefore, to make the measurement at some rate of discharge as near as convenient to that producing the effect desired and then to compute what the discharge would have been at the residual pressure desired. This may be done by applying the fact that the discharge is approximately proportional to the square root of the drop in pressure.

If, for example, the original pressure in the mains before opening the hydrants had been 56 lbs. per sq. in., and the residual pressure during a flow of 2680 gallons per minute had been 32 lbs. per sq. in., then the drop in pressure during that flow was 24 lbs. per sq. in. Suppose now that it were desired to know in this example what the discharge would have been with a residual pressure of 20 lbs. per sq. in. The drop in pressure in that case would have been 36 lbs. per sq. in. It is then merely necessary to multiply the measured discharge (2680 gal. per min.) by the square root of 36 (which is 6.0) and divide by the square root of 24 (which is 4.9).

$$\frac{2680 \times 6.0}{4.9} = 3280$$ gal. per min. which would have been the discharge at 20 lbs. per sq. in. residual pressure.

If Q_1, is the measured discharge with a drop in pressure of D_1; and, Q_2 is the discharge which would have taken place with a drop in pressure of D_2 then the above method may be stated in a general formula as follows:

$$Q_2 = Q_1 \times \frac{\sqrt{D_2}}{\sqrt{D_1}}$$

This method, as stated before, is only approximate and it should not be considered very reliable if the drop in pressure at the measured discharge is very greatly different from the drop in pressure desired. The method is, however, entirely satisfactory for most practical purposes.

Fire flow tests may indicate not only whether the system has the desired capacity or not, but they may be amplified to give

information as to what work should be done to increase the capacity. For example, by taking a record of the pressures in the system during the flow test at various points progressing back toward the source of supply, it may be conclusively shown whether a restriction is in the principal supply mains or whether it is in the local mains adjacent to the test. By cutting out certain mains during the test still further information may be gained as to the actual conditions existing; closed valves or other obstructions, defective hydrants, or large leaks may be discovered and located. This work opens up a great field for the display of ingenuity on the part of the operator since the exact procedure is subject to unlimited variation and depends upon the arrangement of the particular system under test.

For further details and information regarding fire flow tests the reader is referred to a paper published in the *Journal of the American Water Works Association*, Volume 12, No. 2, October, 1924, by Mr. George W. Booth.

Other Uses for Hydrant Flow Measurements

There are many other varieties of tests, measurements and experiments which may be performed on a distribution system through the use of hydrant discharge measurements. They may be used in making determinations of the friction coefficient in certain mains of the system. By isolating a stretch of pipe so that the feed into it is from one end only, a flow through it may be created which can be measured at its discharge from a hydrant or hydrants at the end of the section under test. If pressures are taken simultaneously during the flow at intermediate hydrants or other connections of known elevation along the main, then, from the data so obtained, the loss of head and the friction coefficients of each section may be computed. Obstructions or closed valves may also be located through the unequal drops in pressure in different sections along the line when such difficulties exist.

Such tests are of value in determining the necessity for or advisability of cleaning a main and likewise, in determining the effectiveness of the cleaning after it has been performed. If they are made periodically after cleaning, valuable data will be obtained as to the speed and degree of the return of roughness in the pipe, thereby indicating the true value of the cleaning and the advisability of recleaning or of cleaning other mains. Also the efficacy of corrosion control procedures will be disclosed and the results of changes evaluated.

In those cases where a company's records are inaccurate, loss of head tests may be quickly made to provide an accurate indication of the size of any main which is in doubt.

When flushing out sediment or other deposits from the pipes of a system it is of great value to make a rough check of the discharge of the hydrants or blow-offs in use in order to be certain that a sufficient velocity has been created in the main or mains supplying that point to properly clean them out. From 4 to 6 feet per second is usually considered the minimum that will effectively flush out a main, so that the material remaining will cause no further difficulty by being stirred up by normal flows.

It is difficult to foresee all of the benefits which may come of making tests such as these on a distribution system. One of the greatest benefits is that, no matter what their nature, they will ordinarily result in an unusually thoughtful and detailed consideration of the system on the part of the men who are operating it. The effort to interpret and account for results, and the resulting further tests, will frequently uncover unsuspected conditions quite different from those which originally suggested the tests.

Acknowledgment—At the request of WATER WORKS AND SEWERAGE, the author has revised and added to an article published by him (Journal of the A. W. W. A. for July, 1930), on the same subject. We believe the practical value of this contribution justifies its re-publication.—*Editor.*

[See also "Pipe Flow Diagram" and "Flow Powergraph" which appear in Part III.]

Fire Flows Required for Towns of Various Sizes, by National Board of Underwriters

Population	Required Fire Flow, Gallons per Minute for Average City
1,000	1,000
2,000	1,500
4,000	2,000
6,000	2,500
10,000	3,000
13,000	3,500
17,000	4,000
22,000	4,500
28,000	5,000
40,000	6,000
60,000	7,000
80,000	8,000
100,000	9,000
125,000	10,000
150,000	11,000
200,000	12,000

Over 200,000 population, 12,000 gallons a minute, with 2,000 to 8,000 gallons additional for a second fire.

In residential districts the required fire flow depends upon the character and congestion of the buildings. Sections where buildings are small and of low height and with about one-third the lots in a block built upon, require not less than 500 gallons a minute; with larger or higher buildings up to 1,000 gallons is required, and where the district is closely built, or buildings approach the dimension of hotels or high value residences, 1,500 to 3,000 gallons is required, with up to 6,000 gallons in densely built sections of 3-story buildings.

(*See also table of "Effective Fire Streams," page 191.

Commercial Pipe Sizes for Fire Streams*

Number of 1 ½-Inch Hose Nozzles	Ordinary Fire Streams											
	40 Pounds Pressure		50 Pounds Pressure		60 Pounds Pressure		70 Pounds Pressure		80 Pounds Pressure		90 Pounds Pressure	
	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.
1	4	20	6	23	6	25	6	27	6	29	6	30
2	6	40	8	45	8	50	8	53	8	57	8	61
3	8	61	8	68	10	74	10	80	10	86	10	91
4	10	81	10	90	10	99	10	107	12	114	12	121
5	10	101	12	113	12	124	12	134	12	143	12	152
6	12	121	12	135	12	149	14	160	14	172	14	182
7	12	141	14	158	14	174	14	187	14	200	16	212
8	12	162	14	181	14	199	16	214	16	229	16	242
9	14	182	14	203	16	223	16	241	16	257	18	273
10	14	202	16	226	16	248	16	267	18	286	18	303
11	16	222	16	248	18	273	18	294	18	314	18	333
12	16	243	18	271	18	298	18	321	20	343	20	364
13	16	263	18	293	18	323	20	348	20	372	20	394
14	18	283	18	316	20	348	20	374	20	400	20	424
15	18	303	20	339	20	372	20	401	20	429	24	455
	High-Pressure Fire Streams											
	100 Pounds Pressure		110 Pounds Pressure		120 Pounds Pressure		130 Pounds Pressure		140 Pounds Pressure		150 Pounds Pressure	
1	6	32	6	33	6	35	6	36	6	38	6	39
2	8	64	8	67	10	70	10	73	10	75	10	78
3	10	96	10	100	10	105	10	109	12	113	12	117
4	12	128	12	134	12	140	12	145	12	151	14	156
5	14	160	14	167	14	174	14	181	14	188	14	195
6	14	191	14	200	14	209	16	218	16	226	16	234
7	16	223	16	234	16	244	16	254	16	264	18	273
8	16	255	16	267	18	279	18	290	18	301	18	313
9	18	287	18	301	18	314	18	326	18	339	20	352
10	18	319	18	334	20	349	20	363	20	377	20	391
11	20	351	20	367	20	384	20	399	20	414	20	430
12	20	383	20	401	20	419	20	435	24	452	24	469
13	20	415	20	424	24	454	24	472	24	490	24	508
14	24	447	24	467	24	488	24	508	24	528	24	547
15	24	479	24	501	24	523	24	544	24	565	24	586

To convert cubic feet to gallons, multiply by 7.4805.

In calculating above table, the following assumptions were made: Nozzles, 1 ½-inch smooth bore, playing simultaneously, and attached to 200 feet of best quality rubber-lined hose; pressures measured at hose connections; velocity of water in pipe approximately 3 feet per second.

*Reproduced by courtesy of N. S. Hill, Jr.

GENERAL PAINT CORPORATION—Hill, Hubbell & Co. Division

Lining and Coating STEEL PIPE for Water Mains and Supply Lines

CLEVELAND, OHIO

Offices in Tulsa, San Francisco, Los Angeles, Oakland, Portland, Seattle, Spokane

BITURINE AKWALINE Lining Prevents Corrosion, Tuberculation, Incrustation and assures CAPACITY FLOW

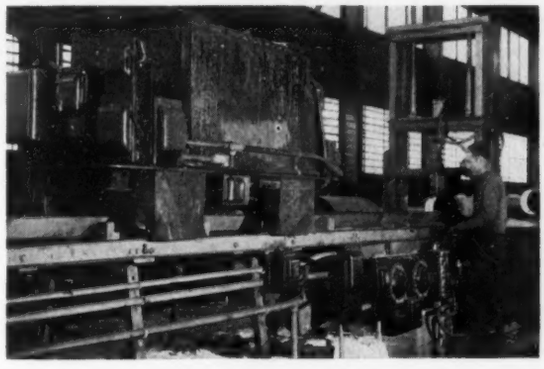
The use of STEEL PIPE for water supply lines is not new! For more than half a century, "big inch" steel pipe has been used—carrying water to many large cities in the United States.

Here are a few of the many inherent and unquestioned supremacies of STEEL PIPE:

Highest bursting strength	Least leakage
Greatest flexibility, ductility	Lowest laying costs
Longest lengths	Greatest, enduring capacity
Fewest joints	Lowest pumping costs

The HILL-HUBBELL Process of applying linings to the more widely used sizes of STEEL PIPE makes it possible for the smaller community, also, to have the many advantages of STEEL PIPE. We line STEEL PIPE from 4½" O.D. to 30" O.D., and coat-and-wrap STEEL PIPE from ¾" Nom. to 30" O.D. Eminent engineers maintain that STEEL PIPE, when Lined inside and Coated-and-Wrapped outside by the HILL-HUBBELL Process, is far more practicable than any other type of pipe.

For ECONOMY and SAFETY—USE STEEL PIPE.



Lining STEEL PIPE

BITURINE AKWALINE Lining in any ferrous pipe prevents tuberculation, corrosion, incrustation, and silting—all of which reduce the original carrying capacity of the pipe. An article on "The Prevention of Corrosion of Pipe" (The American Water Works Association, Volume 16, No. 2, 1936) illustrates the practicability of coal tar lining. Two sections of 6-inch pipe were taken from the Brooklyn System in 1925. One section, laid in 1857, had only one-fifth its original carrying capacity. The other section, laid in 1863, with a coal tar lining, still had, after 62 years of service, its ORIGINAL CARRYING CAPACITY.

In the Hill-Hubbell method, the coal tar enamels are applied, mechanically, in a true multiple coat process. Centrifugal force of the revolving pipe evenly disperses the flow of molten enamel from a slowly withdrawn feed line. The result is a lining of guaranteed minimum thickness and of maximum uniformity. The surface of the lining is as smooth as glass and increases the pipe carrying capacity from 7 to 10% and thereby reduces FOREVER, pumping and operating costs.

Our entire lining application is done AT THE PIPE MILLS, INDOORS. No weather hazards affect the quality of our work. With the most highly developed equipment in the industry to properly handle the coating materials, a Hill-Hubbell job of coal tar enamel lining can not be excelled.

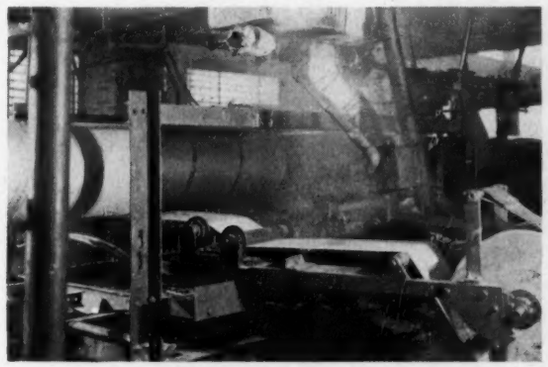
More than 8,000 miles of Steel Pipe have been protected against exterior corrosion by the Hill-Hubbell Process, establishing the unquestioned leadership and acceptance of our method. All our work is done, right in the steel pipe mills, mechanically, indoors—away from all weather hazards.

Proper handling of the coating materials is assured, for we use heating kettles of our own design equipped with positive thermostatic control and tireless mechanical agitation.

Because all bituminous coatings are plastic solids, they need the physical strength given them by shielding reinforcing wrappers. Our method always provides this extra protection, positively bonded to the coating—as it should be.

Because we take pride in our craftsmanship, the final shipping-and-handling wrapper of heavy kraft paper is imprinted with our name. You see our name only on jobs of our Genuine Mill Coating-and-Wrapping.

Mill Coating-and-Wrapping is the modern, proven method of pipe protection.



Coating-and-Wrapping STEEL PIPE

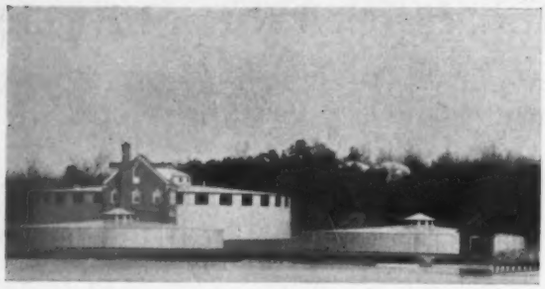
BITURINE AKWALINE PRIMER and ENAMEL

BITURINE AKWALINE Enamel is an all-coal tar pitch enamel developed especially for lining water mains and supply lines. It meets the accepted sagging test at 160° F. and the usual cracking test at —10° F. When your STEEL PIPE is lined with BITURINE AKWALINE Enamel by the HILL-HUBBELL Process, it can not be excelled because the RIGHT enamel is PROPERLY applied. No matter how good the lining is, it must be PROPERLY applied to give 100% protection.

BITURINE ENAMEL

BITURINE Enamel is used for coating STEEL PIPE outside. It is an all-coal tar pitch enamel and has been doing an efficient protection job for over 30 years. BITURINE Enamel, with the additional reinforcement of shielding wrapper, PROPERLY applied at Mills, is now protecting thousands of miles of STEEL PIPE in all parts of the country.

This can NEVER happen to STEEL PIPE lined with BITURINE AKWALINE Enamel



5 m.g.d. Morse Filter Plant, located at Bristol, Conn., with two 400,000-gal. filtered water reservoirs in the foreground.

CHICAGO BRIDGE

Chicago.....2198 Old Colony Bldg. Dallas....1479 Liberty Bank Bldg.
New York.3390-165 Broadway Bldg. Birmingham....1586 North 50th St.
Cleveland...2262 Rockefeller Bldg. Tulsa.....1646 Hunt Bldg.

Plants in CHICAGO, ILL.; BIRMINGHAM, ALA., and GREENVILLE, PA.

BINS, Storage
BREECHINGS, Steel
CHUTES, Steel
FILTRATION PLANTS
FLUMES, Iron and Steel
GAS HOLDERS
HOPPERS, Steel
PENSTOCKS
PIPE, Riveted steel
PIPE, Welded steel

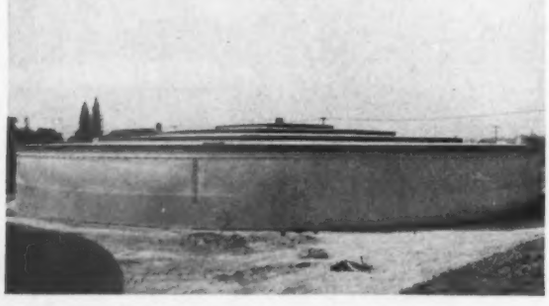
75,000-gal., Parchment, Mich.

100,000 gal., East Gary, Ind.

200,000-gal., Cullman, Ala.

250,000-gal., Marysville, Mich.

200,000 ellipsoidal-roof flat-bottom storage tank at Eden, New York.



This 2,300,000-gal., all-welded steel water reservoir is one of two installed recently in Alhambra, California.

FACILITIES

We are equipped to design, fabricate and erect all types of steel plate work, riveted or welded. When requesting estimating figures on tanks, state capacity, height to bottom for elevated tanks, and describe location.

ELLIPSOIDAL-BOTTOM ELEVATED TANKS

This type of tank is built in a complete range of standard sizes as shown in the accompanying table. The diameter of the tank is relatively large and the depth shallow, reducing the variation in pressure between the upper and lower water levels. The proportions of this design are also well balanced, presenting a pleasing appearance. (See first three tanks shown above.)

Ellipsoidal - bottom tanks are equipped with large steel risers riveted or welded directly to the bottom of the tank. The size of the riser varies from three to six feet, the larger sizes being used in northern climates to prevent freezing.

ELLIPSOIDAL-BOTTOM TANK SIZES

Nominal capacity, gal.	Tank dimensions			
	D	H	B	K
40,000	20'0"	13'9"	5'0"	18'9"
50,000	22'0"	14'0"	5'6"	19'6"
60,000	24'0"	14'0"	6'0"	20'0"
75,000	26'0"	15'0"	6'6"	21'6"
100,000	28'8"	16'0"	7'2"	23'2"
125,000	28'8"	21'2"	7'2"	28'4"
150,000	34'0"	16'6"	8'6"	25'0"
200,000	38'0"	17'6"	9'6"	27'0"
250,000	40'0"	20'0"	10'0"	30'0"
300,000	41'0"	23'9"	10'3"	34'0"
400,000	47'0"	23'2"	11'9"	34'11"
500,000	51'0"	24'3"	12'9"	37'0"
600,000	54'0"	26'3"	13'6"	39'9"
750,000	54'0"	32'0"	18'0"	50'0"
1,000,000	60'0"	34'0"	20'0"	54'0"
2,000,000	80'0"	35'6"	26'0"	61'6"

Height to bottom—any even foot.

RADIAL-CONE BOTTOM TANKS

The radial-cone bottom design was developed to permit the construction of large capacity tanks with a small range in head. (See installations shown above at Marysville, Mich.; Decatur, Ga.; Muskegon, Mich.; and Buffalo, N. Y.) Radial-cone tanks are of sound structural design. They present a pleasing appearance. Construction details such as tower bracing, hand railing, etc., may be varied to secure the desired architectural effect. The accompanying table indicates the proportions for various capacities.

STANDARD RADIAL-CONE SIZES

Capacity (Gallons)	Diameter of Tank	Depth of Tank
500,000	61'	25'
750,000	76' 8"	25'
1,000,000	87'	25'
1,500,000	106'	25'
2,000,000	122'	25'

& IRON COMPANY

Houston.....2919 Main St.
Detroit.....1551 Lafayette Bldg.
Philadelphia..1644-1700 Walnut St.
Boston.1548 Consolidated Gas Bldg.
San Francisco....1083 Rialto Bldg.
Los Angeles...1455 Wm. Fox Bldg.

In Canada: HORTON STEEL WORKS, Limited, Fort Erie, Ontario

PRESSURE VESSELS, Welded
RESERVOIRS, Steel
RECEIVERS, Air
SMOKE STACKS
STANDPIPES

STEEL PLATE WORK
TANKS, Elevated Steel
TANKS, Storage
TANKS, Surge
TANKS, Washwater

Here is one of two 5 m.g.d. Morse Filter Plant units which are installed at Burnt Mills, Md.

500,000-gal., Decatur, Ga.

1,000,000-gal., Muskegon, Mich.

2,000,000-gal., Buffalo, N. Y.

THE MORSE FILTER PLANT

The Morse filter plant is a rapid sand type plant. It is built entirely of steel. The filters, coagulating basins and reservoirs can be located in concentric circles, providing a compact arrangement. A 5 m.g.d. unit covers a circle 100 feet in diameter. The advantages are summarized as follows:

1. All-steel construction offers the same advantages that have proved so desirable in large capacity water storage tanks. No seepage, no cracking, less maintenance expense.
2. Economical first cost. Also requires less ground space per unit of capacity than any other type of construction.
3. Modern. Definitely designed to push obsolescence as far into the future as possible.
4. Flexible in both operation and application. Put in capacity needed at present; add more capacity easily and economically at any time in future.
5. Lower operating costs. Very small loss of head through plant means less pumping cost. Cleaning and maintenance is easier and quicker.
6. Built in a wide range of capacities.

WASHWATER TANKS

We build ellipsoidal, radial-cone or special shaped tanks to give exactly the capacity, head, and pressure variation required for washing filters. These tanks have proved to be more dependable and economical than direct pressure washing.

RESERVOIRS

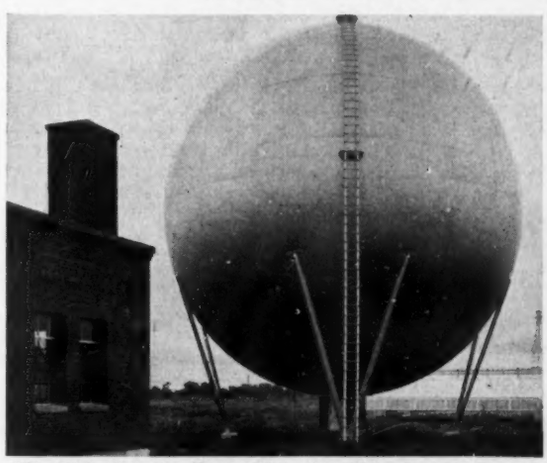
Where natural elevations are available, flat-bottom steel reservoirs provide gravity pressure. They are built in standard sizes or special designs to meet your requirements, of riveted or welded construction, with or without roofs.

SEWAGE GAS HOLDERS

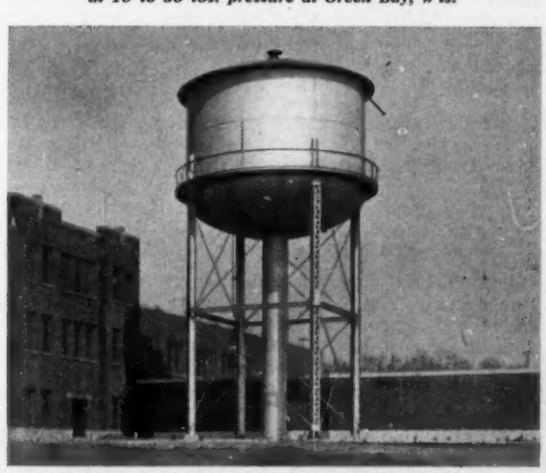
When gas from digesters at sewage disposal plants is utilized, excess quantities produced during peak periods can be stored advantageously under pressure in a Hortonsphere for use during off-peak periods. Hortonspheres are relatively small in size and pleasing in appearance. We also build conventional lift-type gas holders.

INFORMATION

We are always glad to supply municipal officials and waterworks engineers with complete information or estimating figures. Please address our nearest office. There is no obligation on your part.



This 50-ft. diameter Hortonsphere is used to store sewage gas at 10 to 30 lbs. pressure at Green Bay, Wis.



100,000-gal. wash water tank at Michigan City, Ind.

ECONOMY OF ELEVATED STORAGE*

By DONALD H. MAXWELL**

The operating records of the Glencoe, Ill., water works furnish a striking demonstration of economy procurable through the introduction of elevated storage. In this case the savings in pumping costs, resulting from use of an elevated tank, are sufficient to cover all annual costs incident to the project.

The Glencoe pumping arrangements and filtration plant were designed to operate in connection with an elevated tank which was omitted in the original construction and the pumps operated against direct main pressures for about 4 years. In 1932, a 500,000 gallon elevated tank was added and now records under the new conditions are available to show a saving of about 33 per cent in power consumption.

The Glencoe filter plant has two motor driven low lift pumps each of two million gallons rated capacity and three motor driven high lift pumps, of one, two and four million gallons rated capacity respectively. In addition there is gasoline engine driven standby equipment. The average daily pumpage is approximately one million gallons, the rates varying from a minimum of approximately 420,000 g.p.d. to a maximum of 3,300,000 g.p.d. The maximum hourly rate of consumption is approximately 5,200,000 g.p.d. and the minimum hourly rate is about 300,000 g.p.d.

Pumping Conditions With and Without Elevated Tank on the System

Comparison of these consumption rates with the installed pump capacities makes it evident that the high lift pumping operating against direct main pressures, with pumps throttled a considerable part of the time, was necessarily inefficient. The low lift pumping was also inefficient, owing to the desirability of maintaining a full clearwell and thus a 500,000 gallons storage. To do this it was the practice to operate the filters more or less continuously with the low lift pumps throttled. At times these pumps had to be operated at 15 per cent of rated capacity.

With the elevated tank in service the high lift pumps now operate intermittently at about their rated capacity and best efficiency. With present practice, maintaining the clearwell storage at not less than 75 per cent full, is accomplished by running one or two low lift pumps which operate at about rated capacity during approximately the same periods as the high lift pumps are in service.

Improved Pressures

The pressures maintanied in the business district when pumping against main pressures varied over an extreme range of 40 pounds per square inch. The variation was from approximately 28 pounds minimum to 70 pounds maximum. Under present conditions, with the tank in service, a very uniform pressure is maintained, having an extreme range not to exceed 20 pounds. From 35 pounds minimum to 55 pounds maximum is recorded at the business center. The changed pressure conditions are clearly shown on the pressure charts, revealing recording gage pressures before and after providing elevated storage.

Savings in Power Consumed

As now operated the pumps run at capacity from 4 to 24 hours a day depending on the season, whereas formerly they ran continuously during periods of light as well as heavy demands. Much of the time they were throttled thus producing a very considerable sacrifice in efficiency as becomes apparent by comparing the power consumption with and without elevated storage, as shown in Table I.

During 1931 (operating direct pressure) the power consumption averaged 1,835 k.w. hours per million gallons delivered to the mains. During the six months of operation with the elevated tank in service, the power consumption per million gallons

500,000 *Gallon Elevated Tank, Glencoe, Ill.*

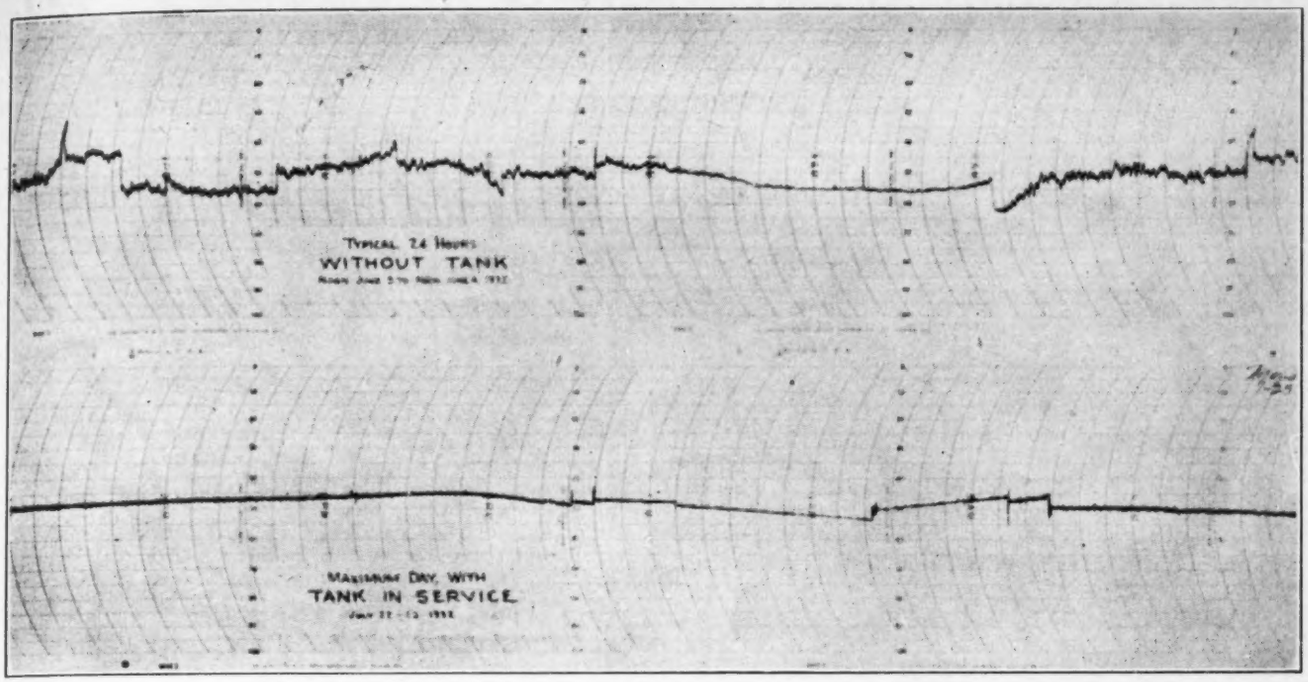
TABLE I—PUMPAGE AND POWER DATA COMPARING OPERATION WITHOUT AND WITH ELEVATED TANK, GLENCOE, ILLINOIS WATER WORKS

Month	Pumpage, million gallons	Kw.hrs. per calendar month	Kw.hrs. per m.g.d.	Kw. max. demand
1931 (without tank)				
January	21.467	47,600	2,220	87
February	17.568	40,000	2,280	78
March	20.265	45,600	2,250	81
April	22.877	47,400	2,070	126
May	29.097	55,200	1,900	174
June	37.153	60,400	1,620	192
July	55.516	80,800	1,450	249
August	56.960	79,600	1,400	246
September	34.030	62,000	1,820	174
October	27.580	59,000	2,140	114
November	23.116	50,000	2,160	102
December	22.362	47,800	2,140	99
Total or average	367,991	675,400	1,835*	
1932 (only those months with new tank in service throughout month)				
March	21.578	27,400	1,270	117
July	45.083	55,200	1,225	186
August	46.437	56,800	1,225	189
September	38.920	47,200	1.210	168
October	23.700	29,600	1.250	174
November	19.502	25,000	1.280	120
Total or average	195,220	241,200	1,235*	

*Weighted average.

*Excerpts from an article which appeared in Water Works and Sewerage.

**Of Alvord, Burdick & Howson, Consulting Engineers, Chicago.



Record Gage Pressures Before and After Elevated Storage Was in Service

pumped has averaged only 1,235 k.w. hours, almost exactly two-thirds of the former power use and much more uniform as shown by the tabulation.

The saving in cost of power due to improved operation, made possible by the tank, cannot be properly shown by direct comparison of power bills for corresponding periods under the old and the new conditions because of the fact that a new power rate was introduced some time after the elevated tank went into service, and also because there has been a decrease in pumpage approximating ten per cent.

The fairest estimate of saving in power cost is obtained by applying the new power rate to the recorded 1931 pumpage as it actually occurred for comparison against the same monthly pumpage if delivered under more efficient operation as now attained with elevated storage. The saving calculated in this manner, amounting to approximately $2,500 a year, is sufficient to cover interest on the investment, depreciation (on sinking fund basis) and maintenance of the tank.

Thus, without added annual cost, the village has been able to avail itself of the many advantages of elevated storage which includes doubling of reserve storage, better fire protection, uninterrupted and more uniform water pressure, greater flexibility of filter and pumping operations and increased plant reliability.

It is worth noting that the saving in cost of power would have been greater if Glencoe had happened to enjoy a uniform rate of power, such as applies in many plants. In reducing the power consumption by 33 per cent the plant is not able to earn proportionately as good a rate. The estimated net average power cost based on the new rate when applied as above explained to 1931 pumpage without the tank nets 1.27c per kw.h., whereas with the tank it is increased to 1.36c per kw.h.

Auxiliary Equipment

The elevated tank is equipped with an altitude valve and a remote indicating water level gage is installed in the pumping station 2⅓ miles away to make practicable the full use of the storage capacity available.

The elevated tank was supplied by the Chicago Bridge & Iron Works. The Glencoe plant is in charge of E. L. Pflanz, Superintendent, and George R. Young is Village Manager.

TABLE OF EFFECTIVE FIRE STREAMS

Using 100 feet of 2½-in. ordinary best quality rubber-lined hose between nozzle and hydrant or pump.

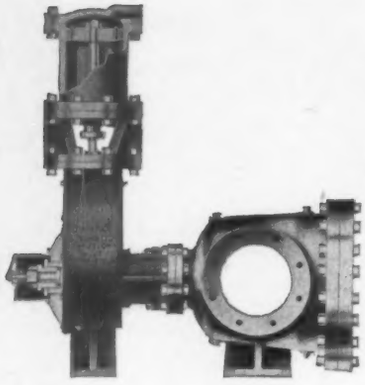
Smooth Nozzle, Size	¾ Inch						⅞ Inch				
Pressure at Hydrants, lbs.	32	43	54	65	75	86	34	46	57	69	80
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70
Press. lost 100′ 2½″ hose	2	3	4	5	5	6	4	6	7	9	10
Vertical Height, feet	48	60	67	72	76	79	49	62	71	77	81
Horizontal Distance, feet	37	44	50	54	58	62	42	49	55	61	66
Gallons Discharged per min.	90	100	116	127	137	147	123	142	159	174	188

Smooth Nozzle, Size	1 Inch						1⅛ Inch				
Pressure at Hydrant, lbs.	37	50	62	75	87	100	42	56	70	84	98
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70
Press. lost 100′ 2½″ hose	7	10	12	15	17	20	12	16	20	24	28
Vertical Height, feet	51	64	73	79	85	89	52	65	75	83	88
Horizontal Distance, feet	47	55	61	67	72	76	50	59	66	72	77
Gallons Discharged per min.	161	186	208	228	246	263	206	238	266	291	314

Smooth Nozzle, Size	1¼ Inch						1⅜ Inch				
Pressure at Hydrant, lbs.	49	65	81	97	113	129	58	77	96	116	135
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70
Press. lost 100′ 2½″ hose	9	25	31	37	43	49	28	37	46	56	65
Vertical Height, feet	53	67	77	85	91	95	55	69	79	87	92
Horizontal Distance, feet	54	63	70	76	81	85	56	66	73	79	84
Gallons Discharged per min.	256	296	331	363	392	419	315	363	406	445	480

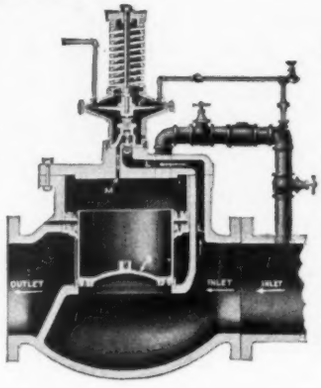
GOLDEN-ANDERSON VALVE SPECIALTY CO.

1350 Fulton Bldg.
PITTSBURGH, PENNA.



THRU-FLOW CONE VALVE

Afford full pipe line flow without friction loss. Always oil lubricated. Axially unseats before it rotates without friction, rub or wear. Especially desirable for sewage disposal service.



ALTITUDE CONTROL VALVE

Assures uniform water level in tanks, standpipes and reservoirs. Suitable for use in single or two-way line service. Heavy internal bronze mounting and air and water cushioning makes valve indestructible. Sizes to 24".

CUSHIONED FLOAT VALVE

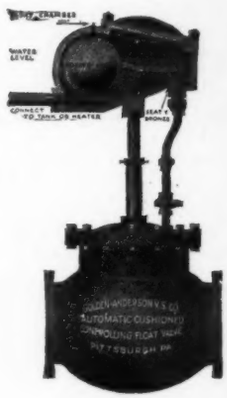
Automatically maintain uniform water levels in tanks, standpipes, etc.

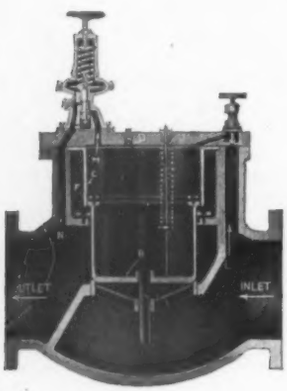
Instantly adjusted to operate quickly or slowly.

Cushioned by water and air, sizes ½ to 24 in.

CONTROLLING FLOAT VALVE

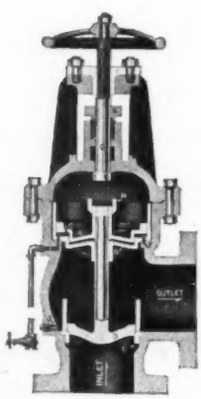
Ideal for heaters, vats, tanks, etc. Valve entirely self-contained and operates without water spill. Sensitive in operation and indestructible due to air and water cushioning and heavy bronze mountings. Sizes to 24".





WATER REDUCING VALVE

Assures positive control of low pressure. Air and water cushioning prevents shock or hammer. Supplied with single or dual pilot controls for any service. Sizes to 24".

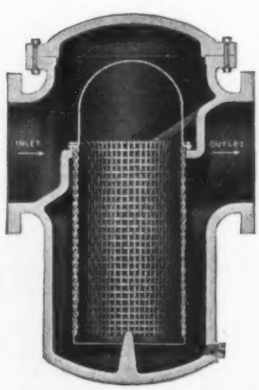


NON-RETURN VALVE

Protect life and property against boiler tube ruptures; also, furnished in Triple Acting style to protect against steam line breaks. Supplied for low and high pressure steam service. Sizes to 12" in angle, globe or elbow patterns.

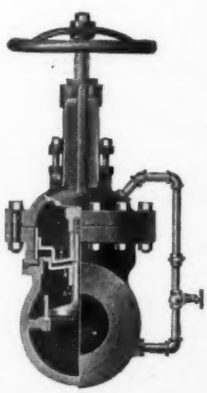
WATER STRAINER

Large capacity with minimum friction loss. Strainer basket quickly accessible and easily cleaned. Basket mesh furnished to suit any service conditions. Sizes to 24".



ENGINE STOP VALVE

The most efficient and dependable automatic stop valve to prevent overspeeding of turbines, engines, etc. Automatically tripped by mechanical or electrical control. Furnished angle or globe patterns to 12" sizes.



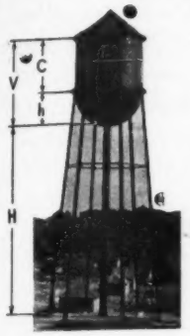
PITTSBURGH-DES MOINES STEEL CO.

Tanks—Plate Fabrication—Structural Steel

Sales Offices at: 3418 NEVILLE ISLAND, PITTSBURGH, PA. . . 919 TUTTLE STREET, DES MOINES, IOWA
ROOM 918—270 BROADWAY, NEW YORK . . . 1222 FIRST NATIONAL BANK BLDG., CHICAGO, ILL.
1223 PRAETORIAN BLDG., DALLAS, TEX . . . 625 RIALTO BLDG., SAN FRANCISCO, CALIF.

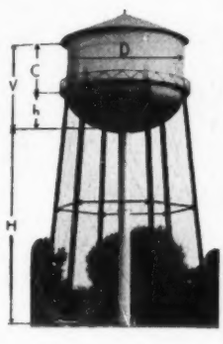
In these tables we have compiled—in compact but complete form—data on steel reservoirs and on the various types of elevated steel tanks. For information as to the application of these various types of tanks, for designs, for specifications, or for estimates—write our nearest office.

Table I—Pittsburgh-Des Moines Standard Hemispherical Bottom Elevated Tanks



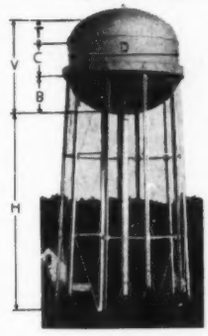
Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity													
				ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
5,000	9	10 0	11 3	11 3	18 9	31 9	38 3	51 9	58 9	72 9	79 9	93 9	100 9	.....	.....	.....	.....
10,000	13	5 11	11 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....	.....	.....
15,000	13	10 11	16 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....	.....	.....
20,000	13	15 11	21 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....	.....	.....
25,000	15	14 7	19 11	44 8	50 0	69 8	75 0	.....	94 8	100 0	.....	125 0	.....	.....	.....	.....	.....
30,000	15	18 5	23 9	44 8	50 0	69 8	75 0	.....	94 8	100 0	.....	125 0	.....	.....	.....	.....	.....
40,000	17	18 5	25 1	46 8	.....	.....	75 0	.....	96 3	100 0	.....	125 0	.....	.....	.....	.....	.....
50,000	19	17 7	25 7	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4		
60,000	19	22 6	30 6	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4		
75,000	21	22 6	30 6	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4		
100,000	24	22 6	31 0	.....	50 0	63 1	75 0	79 7	91 6	100 0	113 1	116 6	125 0	141 6	153 4		
150,000	28	24 2	34 7	46 6	54 10	63 2	75 0	83 4	91 8	100 0	111 10	120 2	128 6	140 3	148 7		
200,000	32	23 4	36 1	45 9	54 1	62 5	75 0	83 4	91 8	100 0	112 7	120 11	129 3	141 10	150 2		
250,000	32	31 4	45 4	45 4	53 8	62 0	75 0	83 4	91 8	100 0	113 0	121 4	129 8	142 8	151 0		
300,000	36	28 4	42 5	45 4	53 8	62 0	75 0	83 4	91 8	100 0	113 0	121 4	129 8	142 9	151 1		
400,000	40	30 0	46 6	44 6	52 10	61 2	75 0	83 4	91 8	100 0	113 10	122 2	130 6	138 10	152 8		
500,000	44	29 9	49 2	43 6	51 10	60 2	75 0	83 4	91 8	100 0	114 10	123 2	131 6	139 10	154 7		
600,000	44	38 6	58 2	Tower heights have not been standardized for these capacities and can therefore be built to suit the requirements in each particular case.													
750,000	50	34 9	57 5														
1,000,000	50	52 0	73 9														

Table II—Pittsburgh-Des Moines Standard Hemi-ellipsoidal Bottom Elevated Tanks



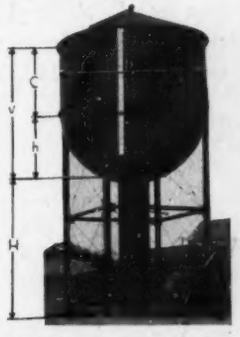
Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity													
				ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
25,000	17	11 9	15 5	46 4	51 8	71 4	75 0	.....	96 4	100 0	.....	126 8	...	.....	.....		
30,000	17	14 7	18 6	46 1	51 5	71 1	75 0	.....	96 1	100 0	.....	126 5	.....	.....	.....		
40,000	21	11 3	16 9	47 5	.....	.....	75 0	.....	97 5	100 0	.....	126 2	.....	.....	.....		
50,000	22	13 2	19 0	.....	57 2	65 6	75 0	85 6	93 10	100 0	113 10	122 2	130 6	142 2	150 6		
60,000	24	12 10	19 4	.....	56 6	64 10	75 0	84 8	93 2	100 0	113 2	121 6	129 10	141 6	149 10		
75,000	26	13 6	20 8	.....	55 10	64 2	75 0	84 2	92 6	100 0	112 6	120 10	129 2	140 10	149 2		
100,000	28	16 2	23 2	.....	51 6	64 7	75 0	81 1	93 0	100 0	114 7	118 0	126 6	143 0	154 10		
150,000	34	14 10	25 0	46 9	55 1	63 5	75 0	83 7	91 11	100 0	112 1	120 5	128 9	140 6	148 10		
200,000	38	15 5	27 0	46 11	55 3	63 7	75 0	84 6	92 0	100 0	113 9	122 1	130 5	143 0	151 4		
250,000	40	18 1	30 0	47 5	55 9	64 1	75 0	85 5	93 9	100 0	115 1	123 5	131 9	140 1	153 1		
300,000	40	23 11	34 0	49 4	57 8	66 0	75 0	87 4	95 8	100 0	117 0	125 4	133 8	142 0	155 0		
400,000	46	22 9	34 11	48 10	57 2	65 6	75 0	87 8	96 0	100 0	118 2	126 6	134 10	143 2	157 0		
500,000	50	23 9	37 0	49 8	58 0	66 4	75 0	81 2	89 6	100 0	112 8	121 1	129 4	146 0	152 5		
600,000	55	21 9	39 7	Tower heights have not been standardized for these capacities and can therefore be built to suit the requirements in each particular case.													
750,000	60	22 4	42 4														
1,000,000	60	35 0	54 0														
1,000,000	65	26 1	47 7														
1,250,000	79	17 4	43 4														
1,500,000	70	37 8	60 0														
1,500,000	79	24 0	50 0														
2,000,000	90' 3"	22 6	50 0														

Table III—Double Ellipsoidal Tanks



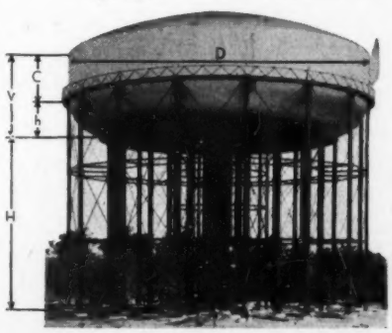
Capacity in U.S. Gallons	Tanks D ft.	V ft.	V in.	H
100,000	28	23	8	Built to Order
150,000	34	26	9	
200,000	38	27	7	
250,000	38	33	7	
275,000	40	33	2	
300,000	42	31	7	
350,000	44	36	6	
400,000	46	35	7	
500,000	50	39	2	
600,000	54	40	0	
750,000	Dimensions on request			
1,000,000				

Table IV—Railroad Type Tanks



Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft.	C in.	V ft.	V in.	H
20,000	15	10	9	16	2	Any height from 15' 0" to 40' 0" in multiples of 5' 0"
25,000	15	14	7	19	11	
30,000	17	12	7	19	0	
40,000	19	13	1	20	6	
50,000	21	13	1	21	1	
60,000	24	10	1	20	3	
75,000	24	15	1	23	10	
100,000	28	13	5	23	7	
150,000	28	14	2	24	7	
200,000	36	15	1	29	2	
250,000	38	17	3	33	3	
300,000	38	23	11	38	3	

Table V—Toroidal Bottom Tanks



Capacity in U.S. Gallons	Tank Diameter (D) when h = 10' 0" and V = 20' 0"		V = 25' 0"		V = 30' 0"		V = 35' 0"		H
	ft.	in.	ft.	in.	ft.	in.	ft.	in.	
750,000	82	0	73	2	66	8	61	8	Built to Order
1,000,000	94	5	84	3	76	9	71	0	
1,250,000	105	4	94	0	85	8	79	2	
1,500,000	115	2	102	9	93	9	86	8	
2,000,000	132	8	118	5	108	0	99	11	
2,500,000	148	0	132	3	120	7	111	6	
3,000,000	162	0	144	8	131	11	122	1	
4,000,000	186	8	166	9	152	2	140	9	
5,000,000	208	6	186	3	169	11	157	3	

Table VI—Steel Reservoirs

Capacity in U.S. Gallons	Diameter ft.	Height ft.	Height in.
50,000	24	15	1
75,000	24	22	7
100,000	30	19	3
125,000	30	24	0
150,000	36	20	1
175,000	36	23	4
200,000	36	26	8
300,000	42	29	4
400,000	42	39	1
500,000	48	37	5
600,000	60	28	10
750,000	72	25	0
1,000,000	84	24	6
1,500,000	96	28	1
2,000,000	120	24	0
2,500,000	132	24	10
3,000,000	144	25	0
4,000,000	168	24	6

ELECTRO RUST-PROOFING COMPANY

38 N. JEFFERSON STREET **DAYTON, OHIO**

"RUSTOP"

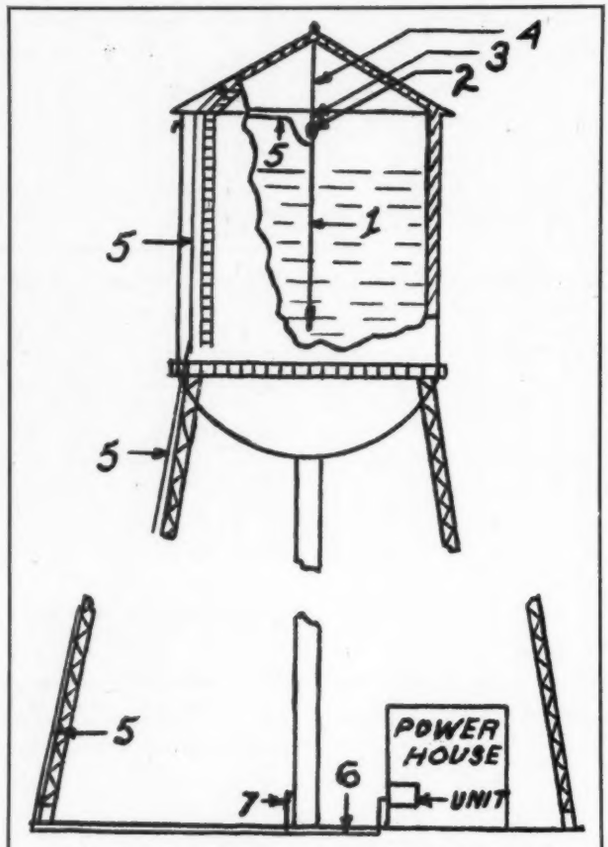
An electrical method of eliminating and preventing rust in steel water tanks

The well-known method of cathodic protection is now successfully applied to steel water tanks and filter troughs *to prevent rust and corrosion.* Many municipalities, as well as commercial organizations, have adopted this system during the past three years.

It works on the principle of an electric current passing from an electrode in the center of the tank, through the water, to the tank itself. (See diagram.) This is made possible by the use of an electrical device called a rectifier, which is built in ratio to the size of the tank. The rectifier is attached to a 110-volt AC light circuit. It changes the current from AC to DC current, required for the process.

HOW THE SYSTEM WORKS

The tank is equipped with one or more polished, stainless steel electrodes, suspended from the top of the tank and insulated from the tank itself. (This is to prevent the tank from grounding the current.) The current passes through the electrodes and flows through the water to make contact with the tank. The tank is grounded at the bottom of the riser, which gives a complete circuit from top to bottom. The current coming in contact with the inside of the tank loosens and removes all corrosion and prevents any further rusting. It leaves a film which covers the metal entirely. Underneath, the tank will be found to be as clean as when it was installed.



TANK EQUIPPED FOR ELECTRIC PROTECTION

1. Solid stainless steel electrode.
2. Insulator—1000 lb. test.
3. Wire cable
4. Safety cable.
5. Service cable wire.
6. Double trenchlay wire.
7. Ground—single trenchlay wire.

INDIVIDUAL INSTALLATIONS

The "RUSTOP" system involves special design and construction for each individual installation, taking into consideration the size of the tank, current density, resistivity and alkalinity of the water, proper amount of current required, etc.

OUTSTANDING ADVANTAGES

1. It is not necessary to empty the tank to install the "RUSTOP" System. You have full use of the tank at all times.
2. "RUSTOP" System eliminates painting of the tank interior below the overflow.
3. The cost of direct pumping (necessary while painting the interior) is eliminated.
4. The water will have no paint taste.
5. "RUSTOP" does not merely cover up old rust—it *eliminates* it.
6. It does not require frequent renewing—it will last many years.
7. It not only prolongs the life of the tank inside—it *completely preserves it from further damage.*
8. Ice floes, which might damage paint in severe weather, will not affect this system.
9. The installation cost is low—seldom exceeding the present maintenance loss on the tank for two years.
10. The consumption of current is low—rarely exceeding that of a 50-100-watt reading lamp.

Patents Pending

Write us for further information and list of users.

A NEW METHOD OF TANK PROTECTION*

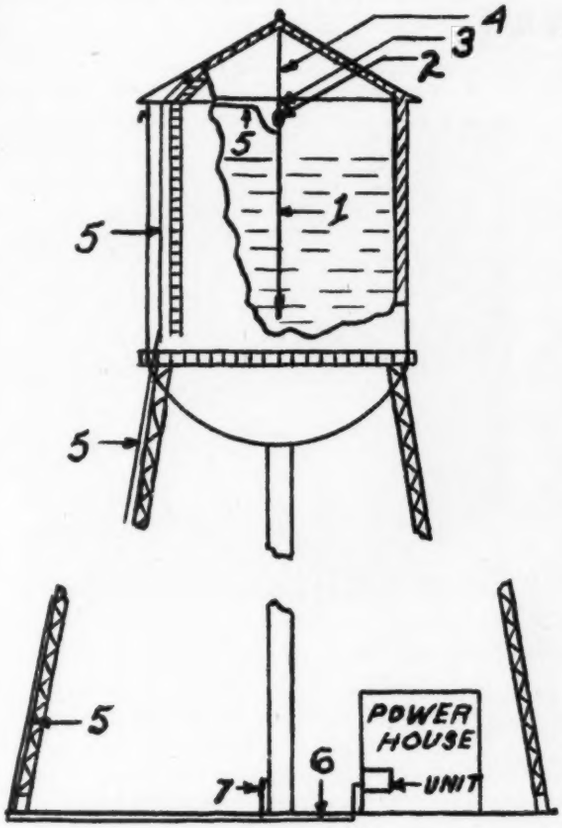
Experiences With Rust Prevention by Cathodic Protection

By O. B. HESS

Supt. of Water Works, St. Clairsville, Ohio

The cleaning and subsequent prevention of rust in water tanks by electricity is a comparatively new subject. It works on the principle of an electric current passing from an electrode in the center of the tank through the water to the tank itself. (See cut.) This is made possible by the use of an electrical device called a rectifier, a small device which is built according to the size of the tank. In our case at St. Clairsville it is approximately eight inches wide, nine inches high and twelve inches long, to service a tank of 200,000 gallon capacity. This rectifier is installed as near the tank as possible and is attached to a 110 volt AC light circuit. It changes the current from AC to the DC current required for the process.

*From Water Works and Sewerage, November, 1938



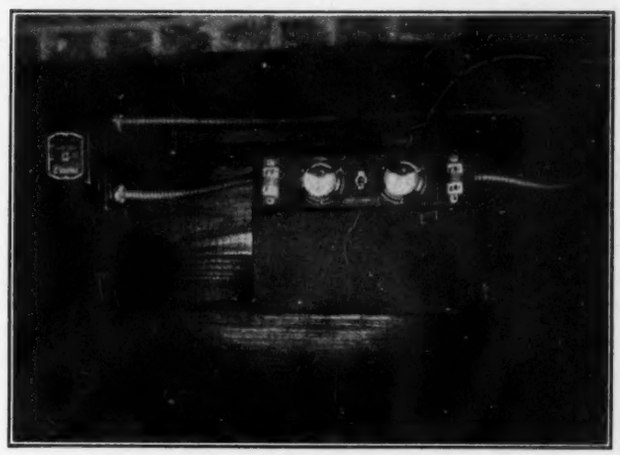
Tank Equipped for Electric Protection
1. *Solid Stainless Steel Electrode*
2. *Insulator—1-000-lb. Test*
3. *Wire Cable*
4. *Safety Cable*
5. *Service Cable Wire*
6. *Double Trenchlay Wire*
7. *Ground—Single Trenchlay Wire*

How the Scheme Works

The tank is equipped with a polished stainless steel shaft called an electrode. (See cut.) In our case the rod is one and one-fourth inches in diameter and fifteen feet long, suspended from the center of the top of the tank and insulated from the tank itself. This is to prevent the tank from grounding the current. The electrode is wire connected at the top direct to the rectifier. The current passes through this electrode and flows through the water to make contact with the tank. The tank is grounded at the bottom of the riser which gives a complete circuit from top to bottom.

Our Experience

The current coming in contact with the inside of the tank seems to loosen and remove all corrosion and prevents any further rusting. It leaves a gray coat, or films, which covers the metal entirely. Upon examination of the practicability of this method of rust prevention the film was rubbed off with the fingers and the tank was found to be as clean and bright as when it was installed. Since the tank has been in service nine years, without anything having been done toward rust prevention, the result was very impressive.



The Rectifier

The cost of the equipment installed by the manufacturers is based on the size of the tank. In our case, on a 200,000 gallon tank it was $325.00. Our operating cost has been approximately 40 cents a month, at 2 cents a KW. rate.

This electric device was built and installed by the Electro Rust Proofing Company of Dayton, O., on a demonstration basis. The results warranted the city purchasing the equipment.

Meter Repair Practices*

Water meter castings are painted by spray gun equipment. The meter casting sets on a turntable which revolves slowly. The colors used are Bronze and Aluminum.

Air chambers have been installed on the influent side of all the meter testing machines. This eliminates water hammer caused by the quick opening and shutting valves, especially effective when testing large size meters.

The use of Monel metal baskets for dipping meter parts in Dearborn 134 solution has been much more economical than the use of cheaper baskets.

An electric drill held in place by a suitable clamp arrangement is used for cleaning meter parts. The drill is substituted for a rotary wire brush. This cleans meter parts in a hurry.

The uses of compressed air in a meter repair shop are many. This added convenience in meter shop repair work will speak for itself.

The use of a hand press similar to the press used on electric drills is a sure way of observing the fit of the disc in the chamber before the meter is put together. This eliminates the guess work connected with tight or ill-fitting discs.

An elevated container of gear lubricant is directly connected to a quick opening valve with string attachment. This gives positive control of the amount of lubricant added to the gear train chamber because it closes so quickly—thus eliminating the mess which generally accompanies the handling of gear lubricant.

*Courtesy, E. T. Cranch, Mgr., New Rochelle (N. Y.) Water Co.

THE NATIONAL WATER MAIN CLEANING COMPANY

Contractors for Cleaning of Water Mains

22nd Floor, 30 Church St., New York, N. Y.

BRANCHES

115 Peterboro St., Boston, Mass.
910 William-Oliver Bldg., Atlanta, Ga.
7103 Dale Ave., St. Louis, Mo.
208 East Forsyth St., Jacksonville, Fla.
3812 Castellar St., Omaha, Neb.
2587 Glen Echo Drive, Columbus, Ohio.
501 Howard St., San Francisco, Calif.
2028 Union Ave., Montreal, Can.

THE NATIONAL METHOD

WHAT IT IS

The National Method is a means of cleaning clogged water mains in order to restore their carrying capacity to normal. By using a water-propelled or cable-drawn machine, tubercles, incrustations and deposits are removed from the pipe lining.

Briefly, the method involves: cutting the pipe in two places, for entry and exit of the cleaning machine; inserting the machine; propelling it by water pressure or by cables through the pipe; placing a riser pipe at the exit, through which first the muddy water, and then the machine, emerge; finally, shutting off the water, removing the riser pipe, and reconnecting the main.

The total time required for shutoff of water in any district is five to seven hours. In an emergency, the pipe can be temporarily made up and service resumed. The work can be done at night if desired.

When a Pipe Lining Is Tuberculated to This Extent, the Frictional Resistance to Flow Is Considerable.

20" Main in a Midwest City Before Cleaning.

WHAT IT DOES

The National Method restores the carrying capacity of pipe to at least 95 per cent of that of new main. (This is our guarantee—the remaining 5 per cent being allowed for possible irregularities in laying—but usually, the main's capacity is restored to very nearly 100 per cent.)

The National Method gives you:

1. Greater delivery
2. Lower pumping costs
3. Reduced insurance rates
4. Clean water

The National Method has for more than thirty years been used in cleaning pipe for cities and towns, private water companies, railroads and industries, many of which have saved the cost of the cleaning job many times over, through savings in pumping costs, or elimination of the necessity for the purchase of new mains, or through having insurance rates lowered, or all three.

LET US CLEAN OUT YOUR CLOGGED MAINS

Not all pipe cleaning jobs are simple. We know how to meet and overcome difficulties that may arise. Don't take chances. Make it a NATIONAL job, and be certain.

Our records are at your disposal. A talk with one of our men places you under no obligation.

WATER MAIN CLEANING*

Some Experiences With the Mechanical and the Chemical Methods

By THOMAS B. RAY†

Skowhegan, Maine

In the past several years, the attention of water works managers and engineers has been increasingly drawn to the problems caused by loss of capacity in pipe lines. It is the purpose of this paper to report some actual experiences in cleaning mains to increase capacity, and to supply information concerning the methods, results secured, and cost of such cleaning.

The Skowhegan Job

Our first cleaning job was performed on the system of the Skowhegan Water Company, serving the town of Skowhegan, Maine. This system, in 1936, was nearly fifty years old.

An investigation made prior to the cleaning work disclosed uniformly unsatisfactory hydrant flows from the 4 and 6-inch mains, and friction coefficients ranging from "C" values of 85 on the 10 and 8-inch mains, down to 40 on the 4-inch mains. Individual hydrant flow tests showed that there were seventeen hydrants out of a total of one hundred which produced less than one standard fire stream. This, with a standpipe full of water. Accordingly, it was decided to have the system cleaned mechanically, the work being carried on continuously from August 10 to September 23, 1936. The cleaning machines used were the standard type furnished by the National Water Main Cleaning Company, consisting of spring steel cutters attached radially to a central shaft or core. (See cut.) All of the 4-inch main, and some portions of the more heavily encrusted 6-inch main were cleaned by the "cable method" in which the cleaner is pulled through the pipe by means of a winch and cable. The balance of the 6-inch and all of the 8-inch mains were cleaned by the "pressure method," in which the cleaner is forced through the pipe by water pressure exerted on a piston at the rear of the cleaner.

Experiences with the Cable Method

In the cable method of cleaning, we found 800 feet to be the longest stretch of pipe which could be cleaned in one operation. However, inasmuch as most of the cleaning operations were between streets, we reduced most of the lengths to between 500 and 600 feet. At the start of operations, excavations are made at the beginning and end of the pipe to be cleaned. A section of pipe approximately four feet long is removed at each end, all services along the main are shut off, and the winch and cable drum is set up at the end of the section of main on the street level. A rubber cone with a small line attached is then floated through the pipe, a temporary connection being made at the first excavation. By means of this pull line, the steel pulling cable is drawn through the pipe, which is then ready for the insertion of the cleaner. When the cleaner has been forced into the pipe, the first cut is closed up by inserting a four-foot piece of pipe to replace the section removed. To speed up the work, we found it desirable in this operation to use mechanical couplings instead of poured joints. When the pipe has been sealed and the water turned on, the winch is operated, and the cleaner drawn through the pipe. The rate of speed depends largely on the condition of the interior of the main, but will average perhaps two or three feet per second. Full water pressure is applied to the pipe during cleaning, in order that the loosened material may be washed along ahead of the cleaner. At the end of the pipe, a 45 deg. bend and riser is attached so that the water and scale which flows out can be discharged into the street and thence to a sewer. (See cut.) At the completion of the operation, the cleaner is pulled out, the second cut patched up, and the services flushed to remove whatever foreign matter may have entered them.

This process sounds simple enough: but, it can become complicated on occasion. The cleaner itself is of rugged construction, capable of cutting through ordinary obstructions, but on several occasions in Skowhegan the cleaners became stuck due to encountering exceptionally large obstructions. On one occasion we removed from the inside of the pipe 35 lbs. of joint lead, in one lump. This lead had run in through a joint which had not been yarned in construction, and made a big enough lump so that the cleaner could not pass. In this instance the cable broke and snapped out of the open end of the pipe, so that the location and removal of the cleaner by digging down and cutting out another section of pipe, developed into a long and tiresome job. On other occasions we removed such unexpected obstacles as pieces of 2x4, stones, pump valves, and even an old pair of overalls.

The Pressure Method

The pressure method of cleaning entails much less equipment and less strong arm work. Of course the same excavations have to be made, but once the cleaner is inserted and the pressure turned on, one has only to follow the cleaner on top of the ground until it pops out of the riser at the end of the main. With a pressure of about 100 lbs. and a volume of about 500 g.p.m., the cleaner progresses about as fast as a man can walk. The noise made by scraping the pipe walls, and a slight vibration at the surface make it fairly easy to follow, except where the pipe is laid under deep cover. It is interesting to note that in the pressure method of cleaning, the cleaner will negotiate a 45 deg. bend with ease, so that it is possible to clean sections of main which have a large deflection.

Either of these methods of cleaning can be performed quickly and without trouble unless some obstruction is encountered. In addition to the objects mentioned above, hazards include partially closed gate valves, old fittings which are not shown on plans, and broken sections of pipe which have been repaired with sleeves or similar devices. Particularly on old systems, there is a probability that some of these difficulties will be encountered, so it is advisable to have on hand a supply of pipe cut to the proper length, repair couplings, and sufficient men to make the necessary excavations as quickly as possible.

Results

The results of the cleaning work in Skowhegan were quite satisfactory. Shortly after the completion of the work, the same flow tests, which had been made prior to the cleaning, were again carried out. The coefficients on the cleaned mains ran from a high of $C = 133$ to a low of $C = 105$. On the 4-inch mains, which had exhibited the lowest coefficients before cleaning, one showed a value of 133, one 130, one 125, one 118 and one 110. The interior of these mains was found to be uniformly smooth and free from any sign of scale or tubercles.

The lowest coefficient, 105, was on a 6-inch main. This main, however, was laid under difficult conditions, with sev-

Set-up for Cleaning by Cable Method

†Chief Engineer, New England Div., Northeastern Water and Electric Service Corpn.

*From Water Works and Sewerage, Aug., 1938.

Close-up Showing Dirty Water and Debris Leaving Main. Later Shoveled Out of Street

eral lateral and vertical deflections, and did not approximate showed a marked improvement over the former condition. All hydrants but one delivered at least one standard fire stream, and the one exception, located at the extreme end of the system, gave a flow of 210 g.p.m. Reviewing the results of the cleaning operation as a whole, it can be said that with the exception of hydrant branches, which were not cleaned, the mains were at 95 per cent of their original condition as far as carrying capacity is concerned. The improvement in fire protection was of course very great, and contributed in large measure to an improvement in the Underwriters Classification. Isolated tests since have indicated almost no loss of value in the coefficients of these mains, presumably due to the control of the corrosiveness of the water.

Costs

In this cleaning operation, a total of 42,266 feet of main was cleaned. This total comprises 4, 6, and 8-inch mains, with the bulk of the total divided between 4 and 6-inch mains. The total cost of the work, including engineering and supervision, labor, material, and rental of the cleaning equipment, was $5,200, a unit cost of 12.3 cents per foot. Although the mains cleaned were chiefly distribution, and hence did not greatly affect the pumping head, the improvement in consumer and fire service was considerable. In a review of the company's rates made in the same year, the Public Utilities Commission decided that a greater portion of the total revenue should be allocated to fire protection. It is safe to assume that the improved fire protection service, resulting from main cleaning, had some influence on this decision. There also occurs the question as to whether or not the increased capacity of the mains would have a favorable effect on the valuation of a system. Where capacity as well as structural condition of the pipe is given proper weight, in determining the condition of a system, it seems to us that an expenditure for cleaning mains becomes an *investment* as well as a betterment.

The Southwest Harbor Job

A more recent mechanical main cleaning job was undertaken in May of 1938 on the transmission main of the Southwest Harbor Water Company, at Southwest Harbor, Maine. This company serves a small community where the peak water demand occurs in the three summer months. During these months, the consumption increases to about three times the average demand for the balance of the year. Between the pumping station and the distribution grid, there is 7,100 feet of 6-inch main, which in the course of some 35 years had become heavily incrusted. The capacity of this line so limited the production of water that during the peak season, it was necessary to operate the pumps from twenty to twenty-four hours a day, and even then it was difficult to maintain an adequate reserve of water in the standpipe. Pitometer tests on this 6-inch main indicated a coefficient of 57 at a flow of 178 g.p.m., which was the maximum delivery of the larger of two electric driven centrifugal pumps. The friction head alone on this line was 70 lbs., necessitating an operating pressure of over 150 lbs. against a full standpipe head.

This main was cleaned by the pressure method during the week of May 3, 1938, the actual cleaning requiring two days. The cleaner was inserted a short distance outside the pumping station, and progressed for about 4,500 feet, where it was stopped. Most of this main being laid in a wooded and swampy area it was difficult to cover it on foot. Unfortunately, the cleaner got ahead of the two men following it, so that when it stopped its exact location was unknown. There followed an anxious period cleaner was finally located and removed. On the following day the cleaner stopped a second time; but, this time, was located and removed in a fairly short time. Both of these stoppages were caused by unlooked-for obstructions in the pipe, chiefly in the form of large stones. After completing the interrupted run through the pipe, the cleaner was put through a second time. Much to our pleasure, it traveled the entire distance in twenty-five minutes without any mishap. The condition of the pipe after the second cleaning was extremely smooth and absolutely free from any deposit.

Results

Pitometer tests between two gauging stations, 6,400 feet apart, showed a total friction loss of only 38 feet at a flow of 250 g.p.m., or a coefficient of approximately C = 130. This reduction in head caused an increase in pumping capacity of 90,000 g.p.d. More important, it allowed the pump to operate at a much more efficient point on its characteristic curve. Before cleaning, this pump consumed power at the rate of 2.04 k.w.h. per m.g.; and, afterward, at the rate of 1.70 k.w.h. per m.g. Translated into dollars, this difference in power consumption represents, for an average year, a reduction in pumping cost of $270. In addition to this financial benefit, the increased capacity relieves the pumps of twenty-four hour duty and makes available a much greater supply of water for emergency uses.

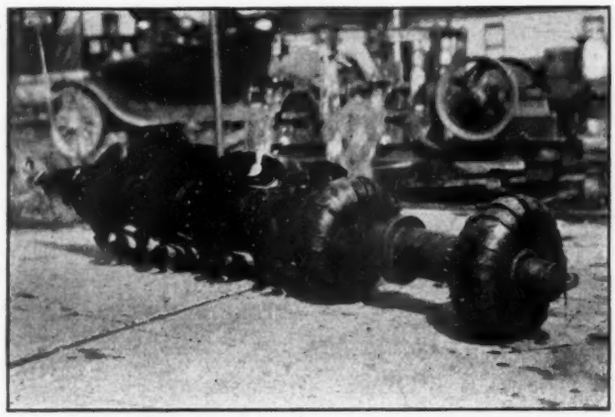
Costs

On this job, the total length of main cleaned was 6,963 feet—the total cost $800, an average of 11.5 cents per foot. If the same coefficient can be maintained, the cost of the cleaning work will be amortized in three and one-half years from the saving in pumping costs.

Experience with Chemical Cleaning

A cleaning job of entirely different character was performed on a main of the Stockton Springs Water Company, at Stockton Springs, Maine, last month. A run of 1-inch galvanized steel pipe 575 feet long was cleaned by the Hydro-Artgel Process of the Devonshire-Arctic Chemical Co. of Boston.

The chemical used is a commercial grade of acid to which has been added an inhibitor which prevents the acid from attacking any ferrous or cuprous metal while it is dissolving or loosening the scale and tubercules. The acid, mixed with a predetermined amount of water, is placed in the pipe and surged back and forth until all the scale and tubercles within the pipe are loosened, disintegrated or dissolved. The acid solution is then drained off, and a neutralizing solution of lime or soda ash added until the pipe interior is restored to its previous condition of pH value. The pipe cleaned at Stockton Springs was on an extremity of the system, connected to a 6-inch main. It was so



The Pressure Method Cleaning Machine. Note the Scraping Blades Ahead of the Twin Propelling Pistons at the Rear.

filled with corrosion products that adequate service to all of the customers was impossible. It had been decided to replace this pipe with copper tubing when the Hydro-Artgel cleaning process was brought to our attention. Inasmuch as the pipe walls appeared to be sound, it was decided to first try the chemical cleaning. An excavation was made at the beginning and end of the 1-inch line, and a third in the middle, so that a section 18 inches long could be removed for inspection during the process of cleaning. An ordinary steel tank of about fifty gallons capacity was set up at each end of the line, to serve as surge tanks. Each was connected to the pipe by means of hose lines. (See cut.) A 105-lb. air compressor was set up midway between the two surge tanks, with a hose running to each tank. Enough chemical solution was introduced to fill the pipe. Then, by means of application of 80 lbs. air pressure to alternate ends, the liquid was surged back and forth through the pipe into the surge tanks, which acted as reservoirs. After the first few surges, it became apparent that the liquid was not traveling the full length of the pipe, and upon trying to blow the liquid out of the pipe into an open tank, it was discovered that the pipe was plugged in two places. Meantime an examination of the removable section showed no cleaning effect. However, the foaming of the acid, which had been removed from the pipe, indicated that a chemical reaction was taking place at points reached by the surging acid. By applying air and water pressure alternately to each half of the pipe line, the obstructions were finally blown out.

Results

Up to this point, the results had been rather discouraging, as the pipe line had plugged up every time the acid or water was applied under pressure. On the following morning, the line was flushed with water under pressure, blown out with air, and seemed to be clear, although the flow of water had not increased appreciably over the original condition. A fresh mixture of acid and water was introduced, and the surging process repeated. After about four hours of effective surging, an inspection of the removable section, and also the two ends, indicated that no scale remained. When a flow test was tried, it was found that the pipe delivered twenty gallons per minute at the lower end, nearly the theoretical maximum under the pressure existing on the 6-inch main.

The line was then filled with hydrated lime solution, which was surged back and forth about four times. After flushing with water, the pH was found to be normal, and the job was considered finished. However, when the services were turned on, it was found that three of them were plugged with the scale which had been loosened from the pipe, and it was necessary to blow these out with air pressure to remove the accumulated loose particles. We considered the result quite satisfactory, as the flow had been increased from about six gallons per minute to twenty, which was sufficient to render adequate service to the limited number of customers on the line. The pipe showed a smooth bright interior similar to new pipe, with faint pit markings where large tubercles had been removed. There was no indication that the pipe itself had been attacked by the chemical. At the measured flow, the friction loss through the pipe corresponded to that shown for "smooth straight new pipe" in the Williams and Hazen tables.

Some Opinions

The method adopted for this particular job is not recommended for the cleaning of small pipes. While the chemical did an excellent cleaning job, the method of application was such as to make plugging of the pipe almost unavoidable as soon as a small quantity of scale had been loosened. Probably a better method would be to pass the chemical in *one direction only* until a large part of the scale has been loosened, removing it by straining from the solution before returning the acid to the line. A surge treatment at this point would then be effective, without the danger of having the pipe plugged. It is probable that in a larger diameter pipe (say 2-inch) this plugging would not have occurred. Of course, the larger the pipe, the less would be the possibility of such plugging. It also seems certain that some amount of scale will collect in the service pipes, from the main to the shut-off cock, during the cleaning operation. These pipes being dead ends, it is impossible to remove this accumulation by flushing the main. When pressure is turned on and the services opened, there is a strong probability that some of the scale will collect at reducing fittings or elbows inside the house plumbing. It is therefore recommended that these services be blown out and opened by means of air pressure applied in the cellar, thus forcing any deposit back into the main, where it can be flushed out of an open end. This operation could be performed after the neutralizing solution had been introduced, and prior to the final flushing of the main with water.

Costs

Unfortunately, no representative cost data can be inferred from the actual cost of this work at Stockton Springs. The job was largely in the nature of an experiment, with the chemical being supplied at a special price, and equipment such as the air compressor and pumps being loaned by other companies in the Northeastern group. However, the cost of the chemical alone, at regular prices for 1-inch pipe, would have been 3½ cents per foot, according to quotations from the Devonshire-Arctic Chemical Co., of Boston, as suppliers of the material. The surge tanks and an acid resistant chemical pump can be rented from the same company; or, if the amount of work justifies the investment, can be furnished by the water works plant. The tanks are ordinary steel tanks and the hose ordinary hose. The main requirement is a satisfactory acid-proof pump. In either case, it seems reasonable to assume that a job similar to the one described could be chemically cleaned for a unit cost not exceeding 10 cents per foot.

Conclusion

Our experiences indicate the following general conclusions about main cleaning:

First, that tar coated cast-iron pipes of 4 to 8-inch diameter can be effectively cleaned mechanically for a cost which ordinarily should not exceed 15 cents per foot.

Second, that coefficients ranging from C-110 to 125 can be expected from the cleaned pipe.

Third, that with proper chemical control, further incrustation in the cleaned pipes can be materially retarded if not completely prevented.

Fourth, that scale and tubercles can be effectively removed from ferrous metal pipes by use of inhibited acid.

[It should also be brought out that while the chemical performance of "Hydro-Artgel" has been proved satisfactory, some study as to the means of application is required. It is recommended to prospective users of this or similar material that a careful individual study be made of each job contemplated, and a suitable method evolved for each. Experience with this method may be well worth the price it costs to obtain in the initial undertaking.]

Main cleaning by either method can greatly improve fire protection and domestic service, can effect large savings in pumping costs by reducing friction heads, can increase the production capacity of individual pump units, and may increase the valuation of a given water system.

From our experience mechanical cleaning for the larger mains and chemical cleaning of the smaller mains and pipe lines seems a worthy combination for securing maximum benefits at minimum cost.

Chemical Main Cleaning Set-Up

One of the Acid Surge Tanks, Carboys of "Hydro-Artgel" Solution and Some of the Scale Removed.

COST OF MAKING A MAIN EXTENSION

A Handy Chart for Quick Reference in Answering Questions of Consumers, Councilmen, and Others

Compiled by

D. R. TAYLOR

Superintendent Water Department, Roanoke, Va.

The following excerpts are taken from an article by D. R. Taylor in the November, 1938, issue of "Water Works and Sewerage," in which he presents a very useful chart kept up-to-date and handy for the reasons here stated by the author.

"When a fellow meets you on the street and says, 'What will it cost me to put water mains in that development of mine in the Fairview Addition,' he might as well ask you 'how high is up,' as to ask you that question without any facts having been given in that one interrogation. You finally pry out of him the length of his proposed extension and then he doesn't know whether he wishes to lay 2,4 ,6 in. or what size of pipe; so, he says, 'what would you lay?' After you explain to him that it depends upon whether he wishes to give the barest domestic needs or install a real system that will meet the approval of the National Board of Underwriters, he decides he would like to have the comparative cost of both. Before he gets through he has asked you for detailed cost of every individual item, going into the laying of several sizes of mains—for instance, the cost of pipe, jointing, labor for laying, backfilling, etc. Most important is the pavement cutting and replacement and ground conditions, for a most nearly correct estimate. I have felt that it pays to know at least the majority of the answers, consequently the more of these questions I was asked about main extensions, the more anxious I was to be able to answer most of them out on the street; so, I sat down at home for a few nights and prepared a tabulated estimate of the cost of mains per foot. I checked these costs with the various actual costs that we have experienced over many years and finally arrived at the average figures, which I believe will answer at least most of the questions that you and I are asked about main extensions. The reader will most likely have to revise some of the figures, depending upon labor conditions, wage scale, overhead; and, of course, present-day prices on pipe. I have also found that this tabulation is a big help and time saver in making estimates on the big extensions that are made by our department in our regular expansion programs.

"Herewith a copy of our quick estimate sheet."

ESTIMATE OF COST OF MAINS PER FOOT

Labor at $0.38 per hour—Pit Cast Pipe at $60.00 per ton—De La vaud, per foot as indicated.

	Galvanized			Cast Iron—Pit Cast Pipe								
Size	1 in.	1½ in.	2 in.	2 in.	4 in.	6 in.	8 in.	10 in.	12 in.	16 in.	18 in.	20 in.
Trench—												
Width	18 in.	18 in.	18 in.	20 in.	20 in.	20 in.	22 in.	24 in.	26 in.	30 in.	34 in.	36 in.
Depth	31 in.	32 in.	32 in.	40 in.	48 in.	52 in.	54 in.	56 in.	58 in.	66 in.	70 in.	73 in.
Cover	30 in.	30 in.	30 in.	36 in.	40 in.	41 in.	41 in.	41 in.	41 in.	44 in.	46 in.	46 in.
LABOR & MATERIALS												
Trench and fill, cu. yd.	$1.90	$1.90	$1.90	$1.90	$1.90	$1.90	$1.90	$1.95	$1.95	$2.00	$2.00	$2.00
Trench and fill, per ft.	0.27	0.28	0.28	0.39	0.47	0.51	0.58	0.66	0.76	1.02	1 22	1.35
Haul pipe	0.02	0.02	0.02	0.02	0 03	0.04	0.05	0.06	0.07	0.08	0.09	0.10
Lay pipe	0.02	0.02	0.02	0.03	0.06	0 09	0.12	0.15	0.18	0.24	0.27	0.30
Pipe (f.o.b. siding)	0.10	0.17	0.22	0.28	0.63	0.97	1.40	1.87	2.38	3.75	4.53	5.22
Joint material	...	...	...	...	0.03	0.04	0.05	0 06	0.07	0.09	0.10	0.11
Sub-total	$0.41	$0.49	$0.54	$0.72	$1.22	$1.65	$2.20	$2.80	$3.46	$5.18	$6.21	$7.08
Overhead—15%	0.06	0.07	0.08	0.11	0.18	0.25	0.33	0.42	0.52	0.78	0.93	1.06
	1 in.	1½ in.	2 in.	2 in.	4 in.	6 in.	8 in.	10 in.	12 in.	16 in.	18 in.	20 in.
BASE COST	$0.47	$0 56	$0.62	$0.83	$1.40	$1.90	$2.53	$3.22	$3.98	$5.96	$7.14	$8.14
For DeLavaud Pipe—												
Pipe (per ft. f.o.b. siding)	...	...	...	...	0.56	0.82	1.17	1.57	2.02	3.09	3.72	4 34
BASE COST—(With labor and materials approximately the same as above)	...	...	...	...	$1 32	$1.73	$2.27	$2.86	$3.57	$5.20	$6.21	$7.13
ADD for Cement Lining	...	...	...	...	$0.03	$0.06	$0.10	$0 13	$0.17	$0.24	$0.27	$0.30
ADD for Cutting and Restoring Pavement												
2-in. Penetration	$0.20	$0.20	$0.20	0.22	0.22	0.22	0.23	0.25	0.27	0.31	0.34	0.36
8-in. Penetration	0.48	0.48	0.48	0.49	0.49	0.49	0 57	0.62	0.68	0.76	0.84	0.90
8-in. Concrete	0.70	0.70	0 70	0.75	0.75	0.75	0.80	0.87	0.95	1.05	1.15	1.20
Brick on Concrete Base	1.20	1.20	1.20	1.30	1.30	1.30	1.40	1.54	1.70	1.90	2.10	2.20

NOTE: All costs based on hand labor for trenching and backfilling, except compressed air used to cut pavement, drill hard rock and tamp backfill. BASE COSTS based on best conditions in non-congested sections.

ADD TO LABOR COSTS AS FOLLOWS:
10% for Intermediate Sections
20% for Congested Sections
110% for Shale
210% for Hard Rock and 6-in. Extra Depth of Trench for Clay Cushion.

For Fittings and Valves add 2% to 10% to BASE COSTS depending upon number and construction methods.

COMPRESSED AIR FLUSHING OF SMALL MAINS*

By R. F. BROWN

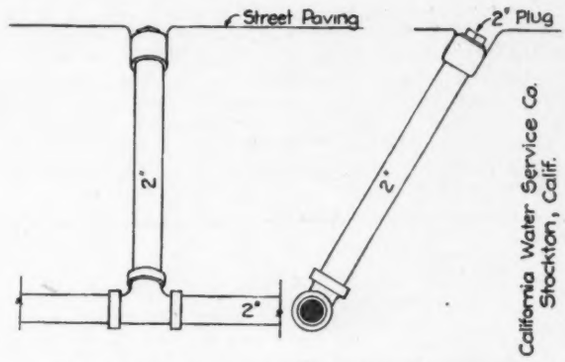
Plant Manager, California Water Service Co., Stockton, California

R. F. Brown

Many water systems in the older California towns, like Topsy, just grew without any suggestion of planning for the future. Stockton was no exception. As a consequence we found ourselves with a great many 2-inch lines in the thinly populated areas.

We have for many years followed the practice of flushing small mains and all dead ends regularly by opening fire hydrants and flusher valves and simply allowing the water to flow from the main under normal pressure of 45 pounds until the main is apparently clear. Under this program all dead ends and all small mains are given ordinary flushing, approximately at intervals of every two months.

This method, however, does nothing but freshen the water in the dead ends and small mains. In order to effect a more lasting cure for taste and odor complaints, we decided to try boosting the pressure in the main with air to attempt to break loose more of the troublesome algae and other deposited material that attaches to the pipe wall. All of our dead ends, regardless of size, and at least every other block of our 2-inch lines have what we call flusher-risers installed for the convenience of our periodical flushing program—see sketch.



RISER CONNECTION TO 2" MAIN FOR FLUSHING

Air Flushing Operations

Compressed air is put into the line through a service connection midway between two flusher-risers after we have first closed the shut-off valves on the intervening services. The valve on the flusher-riser is then opened. All water in the line is forced out through the riser, by air under 90 pounds pressure. As soon as the air has expelled all the water from the line it is shut off and water under our ordinary pressure is run through the line to sweep out, through the flusher-riser, all particles of scale, sand or foreign matter that have been loosened by the air "shooting." We proceed in this manner alternately turning into the line air under 90 pounds pressure and water at 45 pounds until the flushing water leaving the risers no longer carries with it any scale or other foreign matter.

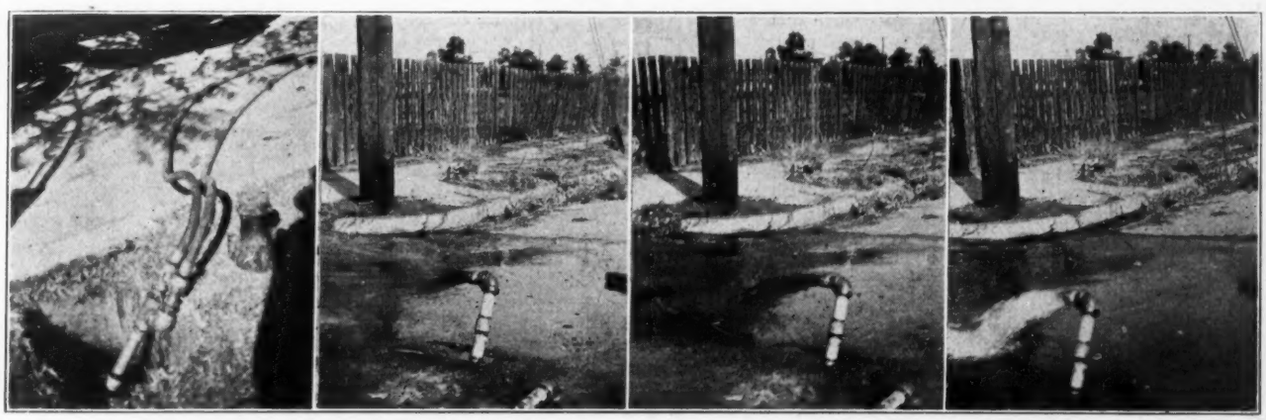
This system is apparently successful in accomplishing our purpose and it is economical, because the equipment required is only a portable air compressor and an air storage tank to provide a volume of air under pressure. No expensive cutting of mains or pavement is required and most jobs can be handled with a three-man crew.

When we first started this system we cleaned 40,000 feet of line, mostly 2-inch, over a period of two months. The cost was from 60 to 90 cts. per hundred feet, depending upon the number of services which had to be shut off and turned on again.

The success of this method of flushing is measured by the almost complete absence of the usual recurring taste and odor complaints from consumers served by mains thus treated. It is problematical how soon we will have to repeat this treatment, because from no consumer on the first line so treated has there yet developed a recurrence of complaints.

A secondary result, not anticipated, is the increase in carrying capacity of the 2-inch lines brought about by the loosening and blowing out of a great deal of scale. Thus has resulted a reduction in complaints of poor pressure as well as the taste and odor complaints.

A Self-Told Story



Air Lines Connected (This Time Through House Service at Curb Line)

First 90 Lb. Air Shot. (Note Extension Attached to Flushing-Riser)

First 45 Lb. Water Flush. (No Argument About Need to Eye or Nose)

Clear Water (Shooting and Flush Repeated As Indicated)

*From WATER WORKS AND SEWERAGE, April, 1937.

WATER SERVED AT WELL-WATER TEMPERATURE

By WM. M. RAPP

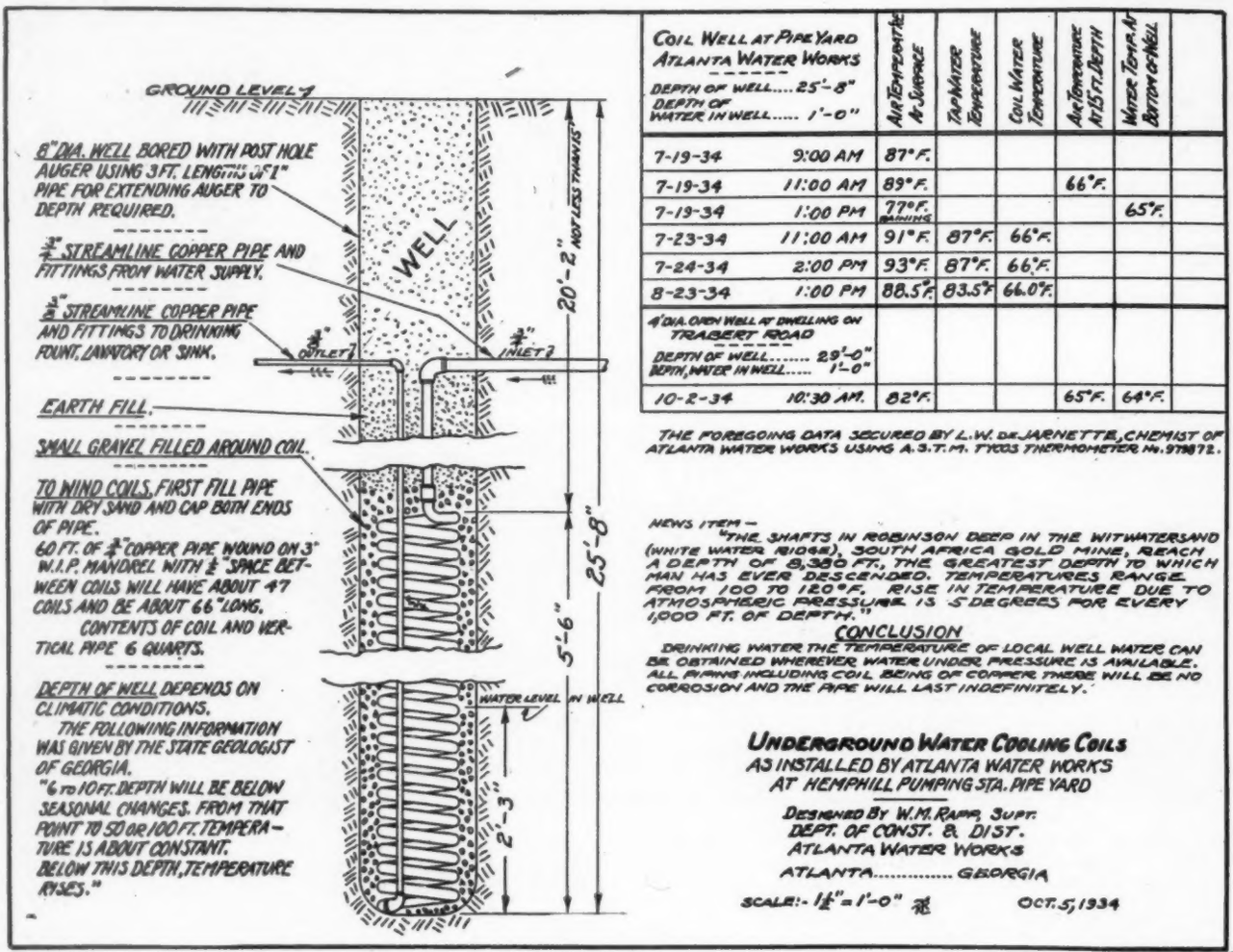
Superintendent of Distribution, Atlanta Water Department, Atlanta, Ga.

A cool drink of pure water on a hot day is very refreshing but few municipalities or private concerns are equipped nor can they afford to supply artificially cooled water to their drinking fountains in parks, on golf links and elsewhere.

The Atlanta Water Department has had two ground water-coolers, similar to the one shown in the accompanying illustration, in service for the past four years and these proved to be so satisfactory that a third has been installed. From the functioning of this last installation the data shown on the sketch was obtained.

When air temperature was 93 degrees F. the tap water temperature from the city mains was 87 degrees F., but the temperature of the water from the depth-cooler was 66 degrees F. A check up against water temperatures in wells in the vicinity showed that the warm tap water, after passing the copper coils of the earth cooler, was the same temperature as waters in the wells.

The accompanying sketch tells its own story of how the coolers are constructed and the results obtained.


GROUND LEVEL
8" DIA. WELL BORED WITH POST HOLE AUGER USING 3 FT. LENGTHS OF 1" PIPE FOR EXTENDING AUGER TO DEPTH REQUIRED.
¾" STREAMLINE COPPER PIPE AND FITTINGS FROM WATER SUPPLY.
¾" STREAMLINE COPPER PIPE AND FITTINGS TO DRINKING FOUNT, LAVATORY OR SINK.
EARTH FILL.
SMALL GRAVEL FILLED AROUND COIL.
TO WIND COILS, FIRST FILL PIPE WITH DRY SAND AND CAP BOTH ENDS OF PIPE.
60 FT. OF ¾" COPPER PIPE WOUND ON 3" W.I.P. MANDREL WITH 2" SPACE BETWEEN COILS WILL HAVE ABOUT 47 COILS AND BE ABOUT 66" LONG.
CONTENTS OF COIL AND VERTICAL PIPE 6 QUARTS.
DEPTH OF WELL DEPENDS ON CLIMATIC CONDITIONS.
THE FOLLOWING INFORMATION WAS GIVEN BY THE STATE GEOLOGIST OF GEORGIA.
"6 TO 10 FT. DEPTH WILL BE BELOW SEASONAL CHANGES. FROM THAT POINT TO 50 OR 100 FT. TEMPERATURE IS ABOUT CONSTANT. BELOW THIS DEPTH, TEMPERATURE RISES."
WELL
OUTLET ¾"
INLET ¾"
20'-2" NOT LESS THAN 15'
25'-8"
5'-6"
2'-3"
WATER LEVEL IN WELL
COIL WELL AT PIPE YARD ATLANTA WATER WORKS
DEPTH OF WELL..... 25'-8"
DEPTH OF WATER IN WELL..... 1'-0"
AIR TEMPERATURE AT SURFACE
TAP WATER TEMPERATURE
COIL WATER TEMPERATURE
AIR TEMPERATURE AT 15 FT. DEPTH
WATER TEMP. AT BOTTOM OF WELL
7-19-34 9:00 AM 87°F.
7-19-34 11:00 AM 89°F. 66°F.
7-19-34 1:00 PM 77°F. RAINING 65°F.
7-23-34 11:00 AM 91°F. 87°F. 66°F.
7-24-34 2:00 PM 93°F. 87°F. 66°F.
8-23-34 1:00 PM 88.5°F. 83.5°F. 66.0°F.
4' DIA. OPEN WELL AT DWELLING ON TRABERT ROAD
DEPTH OF WELL..... 29'-0"
DEPTH, WATER IN WELL..... 1'-0"
10-2-34 10:30 AM. 82°F. 65°F. 64°F.
THE FOREGOING DATA SECURED BY L.W. DE JARNETTE, CHEMIST OF ATLANTA WATER WORKS USING A.S.T.M. TYCOS THERMOMETER No. 9T1872.
NEWS ITEM —
"THE SHAFTS IN ROBINSON DEEP IN THE WITWATERSAND (WHITE WATER RIDGE), SOUTH AFRICA GOLD MINE, REACH A DEPTH OF 8,380 FT., THE GREATEST DEPTH TO WHICH MAN HAS EVER DESCENDED. TEMPERATURES RANGE FROM 100 TO 120°F. RISE IN TEMPERATURE DUE TO ATMOSPHERIC PRESSURE IS 5 DEGREES FOR EVERY 1,000 FT. OF DEPTH."
CONCLUSION
DRINKING WATER THE TEMPERATURE OF LOCAL WELL WATER CAN BE OBTAINED WHEREVER WATER UNDER PRESSURE IS AVAILABLE. ALL PIPING INCLUDING COIL BEING OF COPPER THERE WILL BE NO CORROSION AND THE PIPE WILL LAST INDEFINITELY.
UNDERGROUND WATER COOLING COILS
AS INSTALLED BY ATLANTA WATER WORKS AT HEMPHILL PUMPING STA. PIPE YARD
DESIGNED BY W.M. RAPP, SUPT. DEPT. OF CONST. & DIST. ATLANTA WATER WORKS
ATLANTA..... GEORGIA
SCALE:- 1½" = 1'-0"
OCT. 5, 1934
S-75

Underground Water Cooling Scheme of Atlanta Water Department

IMPROVED METHOD OF MAKING WET TAPS*

By E. T. CRANCH

Manager, New Rochelle (N. Y.) Water Co.

It is assumed that all water works men are familiar with the ordinary hand operated machines for the making of wet-taps for branch connections. These machines have been on the market for many years and have certainly saved water works men many hours of labor. It has also eliminated the inconvenience to the consumer of having to get along without water for several hours while a tee is being cut in the line and a valve installed on the branch.

The hand operated machine, while a great convenience was, however, tedious to operate. A six or eight inch tap would take two or three hours to cut and the larger taps much longer. It would also take not less than three men, working in relays, to operate the machine successfully.

For plants which carry an air compressor unit in their equipment, there is now a means for making these taps quickly and easily. The old hand-type machine can be readily equipped with a bracket to permit the use of a compressed air motor and with a three-horse air motor an eight inch tap can be made in less than half an hour. With this arrangement it is also possible for one man to operate both the motor and the drill feed.

The accompanying illustration shows this machine in operation.

Equipping the machine with the motor-drive does not interfere with its continued use as a hand machine whenever conditions warrant, or should compressed air not be available at some time. It is only necessary to unscrew four stud bolts and remove the motor bracket. The machine is then ready for hand operation as before.

With the use of the air operated tapping machine we have recently made an 8-inch connection to a 12-inch main of class "B" pipe. In timing the whole operation it took just 90 minutes from the time the men started to place the sleeve on the pipe until the job was completed and the machine removed. The actual drilling time was, in this case, only 11 minutes.

The accompanying illustration is a picture made on an earlier job. The tapping machine, which is not new, was purchased some years ago from the A. P. Smith Mfg. Co. The compressed-air motor was supplied by Ingersoll-Rand Co.

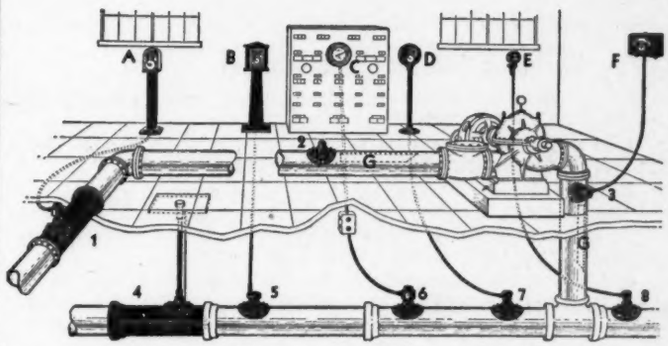
Hand Operated Tapping Machine With Labor and Time-Saving Air-Motor Drive Unit

R. W. SPARLING

LOS ANGELES 945 North Main | CHICAGO 3104 Michigan | CINCINNATI 622 Broadway | NEW YORK 101 Park Ave.

MAIN LINE

Water Measuring Equipment



TYPICAL SPARLING INSTALLATIONS

1. SPARLING Tube Meter installed in pump discharge, and operating Indicator-Totalizer-Recorder A by electric control. Straightening Vanes in tube permit location of meter even at short distance from elbow.

2. SPARLING Totalizing Meter on pump discharge only short distance from pump and check valve, but protected by straightening vane G.

3. SPARLING Meter in vertical suction pipe. Pump and elbow just above but "down stream" from meter, are not objectionable.

4. SPARLING Bell and Spigot Tube Meter with Extension Register, bringing Totalizer to convenient reading position at floor level of pump station.

5. SPARLING Saddle Type Meter connected by flexible cable, less than 15 feet long, to Indicator-Totalizer-Recorder B.

6. SPARLING Meter equipped with electrical remote control to Rate-of-Flow Indicator C.

7. SPARLING Saddle Type Meter connected by cable to floor type Indicator-Totalizer-Recorder D.

8. SPARLING Meter with cable connection to Extension Register E.

Bulletin 305 will be sent upon request

R. W. SPARLING

METERING: PRACTICAL METHODS OF PROCEDURE*

By E. H. RUEHL†
Richmond, Va.

"To meter or not to meter?" That is the question.

Those who have gone through the problem of making initial installation of water meters know what significance these few words can have and what discussions can be caused thereby.

However, metered water service is being acknowledged more and more as being the best all-round method of distributing the indispensable commodity, water. This is especially true since the unprecedented drought of 1930, and I am sure that if more communities were metered at that time the effects of the drought would have been less severe due to the lessened wastage of water.

Why Services Should Be Metered

There are many good reasons why water services should be metered, a few of which are:

1. It is the fairest way of selling water, as all customers pay in proportion to their respective consumptions.

2. The water department or company has a pretty good check on the amount of water sold and by comparison with readings of a master meter can better establish losses and leakage and thereby reduce waste in the system in general.

3. Leaks in consumers' service lines can better be located.

4. Knowledge of the various water consumptions is essential in establishing equitable water rates, and the only way in which this information can be obtained and analyzed is by metering of all services.

In some cases, especially in the municipally owned plants, there are certain institutions, such as schools, hospitals and the like, that are supplied with water without charge, and these should be metered and read regularly to get the full benefits of 100 per cent metering.

And here let me digress a little to state that the words municipally owned are generally a misnomer, as in the majority of cases the municipality has a large obligation in the form of outstanding bonds, and the only part that is really municipally owned is the amount covered by bonds purchased back, or some such similar item. This is mentioned here because in the municipally operated plants we are so often confronted with the statement that the people own the plant and for this reason they should have all the water wanted for some flat rate that is nowhere commensurate with the cost of producing the water, the fixed charges being lost sight of entirely.)

5. It has been proven that as meters are installed that consumers' wastes have been reduced and this in turn effects economies in the amount of power required to pump, if it be a pumping plant, and in treatment costs, which are getting higher and higher every day.

6. As the water requirements of the city are kept within bounds and more or less controlled, the size of the treating and pumping plants and storage and distribution systems are kept to a minimum, thereby keeping capital investment to a minimum, as well as the necessary interest and sinking fund charges, which all result in keeping of the water rates at the lowest possible figure.

7. As the time will most likely come when sewage treatment will become necessary in a good many places, the lowering of the water losses and wastes will redound to the town's advantage in requiring a plant of smaller capacity than would be necessary if water usage and wastage were uncontrolled. Likewise, sewage pumping costs will be less.

With all these reasons in favor of metering, the only ones against it are generally found to be caused by the selfish motives wherein certain customers may want to use unlimited quantities of water without paying a just price therefor. This can be overcome in a great many cases by explanation, and, in spite of the fact that many may be adamant at first, good results are usually obtained.

Another argument against metering is sometimes set forth in that it is claimed that sanitary conditions will not be maintained if water usage be curtailed due to the installation of meters, but it has been shown that for all purposes about 25 gallons per capita per day is all that is absolutely necessary. Under any ordinary rate the cost for this requirement for the average family for an entire month would be modest, in most cases less than the cost of one filling of the gasoline tank of the automobile.

It can therefore be seen that metering is beneficial to both the municipal plant or privately owned company as well as to the consumer, since it contributes a means of compiling equitable rates and keeping bills to a minimum.

Ownership and Location of Meters

Since the type of meter and location of meter setting is governed to some extent by geographical location and local conditions, the remarks that are to follow must of necessity be confined more or less to a particular section and will apply to Virginia.

The ownership and location of the water meter are two subjects on which divergence of opinion exists. In the writer's opinion, the meter should be owned by the water department or company (being charged to capital account) and all maintenance should be done by the owners and charged to operating costs. In Virginia the meter setting just inside the curb line offers so many advantages over other locations that these readily outweigh any disadvantage in the nature of a small additional installation cost, should this be the case. In a good many houses in this section of the country there are no basements in which to locate a meter.

Advantages of Outside Setting

The advantages of such outside setting, located in the sidewalk space, are in general as follows:

1. Meter reading is greatly facilitated due to the fact that the reader never needs to wait for a response from the householder on knocking, and should the party be absent it would necessitate making another trip to get the meter reading if the meter were located inside the house. The distance the meter readers have to walk is lessened when outside settings are used, and this in turn permits more meters to be read per day.

2. The meter is always accessible to water department employees for reading, inspecting, testing and repairing.

3. The danger of the meter readers and other water department employees from attacks from vicious dogs is eliminated.

4. The chance of unauthorized persons entering the house in the guise of water works employees is greatly eliminated.

5. Chance of the meter being covered by rubbish, coal, kindling wood, etc., is done away with when the outside setting is used.

6. More accurate readings can be procured when outside settings are used because of better lighting outside than generally exists in basements, under porches or other places where meters might be set.

7. The line of separation between the water department and property owners' liability is clearly defined and there is not much chance of unauthorized connections being made behind the meter.

8. In case of necessity of cutting off the water for non-payment of bills there can be no dispute as to entering the premises if the meter and control are located at the curb line.

9. The outside setting should be in a locked box and, as it is below the ground, is not so apt to be tampered with as would a setting in a more conspicuous place not protected by a box.

10. Less danger of damage to the meter by hot water exists if set at the curb.

11. Danger from freezing is practically eliminated in a well set meter, and in case of fire in the building supplied the meter is not in danger of being destroyed.

In view of all these reasons the writer is of the opinion that the entire meter setting, including the necessary cut-off valve, should be located in the sidewalk space behind the curb line, and that the water department's or company's maintenance and obligations should stop at the customers' side of the meter.

Type of Setting

The following remarks apply to the smaller size meter up to 1-inch, and when larger sizes than this are used the condition must be studied separately and settings made to suit.

It is realized that a properly set meter, although not always the cheapest, will receive more attention in general from the water works operatives and in turn pay higher returns to the department.

It is a good plan to set the meter in a yoke with at least a control valve at the inlet side, although some prefer valves at

*From WATER WORKS AND SEWERAGE.

†Field consultant, Virginia League of Municipalities. Former City Manager, Bluefield, Va.

both the inlet and outlet sides. This does away with the customary curb stop and box.

The meter in its yoke, and with the control valve, should be set in an earthenware, concrete or iron box with sufficient clearance between the risers, if they be used, that the cold ground outside cannot cause the water in the pipes or meter to freeze. A type of box that has proven very satisfactory in our section of the country is one 18 inches in diameter and 24 inches deep, with side slots at the lower end to accommodate the varying depths of the service pipe. The latter, we feel, should be about 24 inches below the ground.

It is important that a lid be provided that fits the top of the box tightly, preferably being locked on with some kind of a locking device. If the lid is fastened on there will be no circulation of air in the box and consequently less danger from freezing. Another advantage is that if the lid is kept on tightly there is less danger of persons tampering with the meter or of pedestrians catching their feet in the hole, with a possible damage suit resulting.

It is also very important that the bottom of the box extend below the maximum frost line so that the warm air from below can rise up around the meter and risers and keep the atmosphere in the box above freezing. In extreme cases it has been found that a smaller tile pipe about 8 inches in diameter put vertically into the ground below the bottom of the regular box (to reach warmer levels) overcame freezing troubles by admitting warmth from below.

Meter Reading

In the writer's opinion, meters should be read monthly, if this is possible, as by so doing a closer touch is kept on losses and wastes, and due to the visiting of each meter every thirty days the stopped meter and other irregularities can be more effectively dealt with. In case a customer has a leak he can be notified within a reasonable time if the meters are read monthly, but if they are read, say, quarterly, the amount of leakage passed will more likely be an appreciable amount and cause some disagreeableness when an attempt is made to collect the bill.

Experiences at Bluefield, Virginia

If you will pardon personal experiences, it may be of some interest to tell how the town of Bluefield recently attacked the problem of setting 700 meters at the rate of something like 100 per week. This was carried on as follows:

A work sketch was first made up and the various kinds of equipment decided on. After the meters, yokes, boxes and covers were ordered out, some figures were made up giving the length of pipe to be cut from the service to allow for elbows, yoke, valve, etc., and the vertical distance that cover, meter, yoke and fittings required was figured and each made into a constant.

Actual installation started with several men digging holes, located from the curb boxes wherever possible, in a certain well defined section so that one foreman could keep all things going. Two men, both of whom had some previous pipe fitting experience, were formed into a "gang" and given instructions how to set the meters, and they then worked together for about a day. These men then were given a helper each and two setting "gangs" were formed and these two helpers were in turn given helpers and four setting "gangs" were formed in a few days. The work was carried through, with as many men as were necessary to prepare the holes ahead of them.

Tools Required

Each of these setting gangs of two men each was furnished with a ratchet die holder and one-half and three-quarter inch dies, a hack saw, two 10-inch Stillson wrenches, a pipe vise attached to a four-legged board, a home-made wooden straightedge, and a pair of hip boots. The men provided their own rules. The meters, yokes, boxes, covers, pipe, etc., were supplied to the location by a Ford truck. Galvanized nipples of various lengths were purchased and used wherever possible, as they could be purchased cheaper than we could buy, cut and thread the pipe.

When the hole was opened down to the service pipe the meter-setting gang (two men) came along and the first thing they did was to lay the straight-edge across the hole and measure down to the service pipe, and from this the proper "constant," referred to above, was subtracted, which gave the length of risers necessary to bring the top of the meter to the desired point below the meter box lid. If there was a standard nipple of length somewhere near this dimension it was used. If not, the helper would cut pipe to the proper length and thread it. The meter setter in the meanwhile would be cutting a piece of pipe predetermined length out of the service line and threading the cut ends for elbows. The risers were then screwed in and the yoke and meter set, after which the box was put in the hole. By using a set of specially made hooks the box was easily adjusted around the meters and risers, and the cover put on.

Two men constituted the back filling gang and followed up all setting gangs, backfilling all holes and seeing that the lids were properly fastened.

If the existing cut-off in the service line was so that it could be used to control the water it was used but if not the meter setter would cut and thread the pipe under pressure, which only took a very few minutes. He would screw the riser pipe with control valve on, bail out the hole, and go on without having to dig back to the main or cut the water off of a section of the town. The water lost amounted to very little.

One foreman looked after the entire job and 700 meters were set at the rate of about 100 per week.

The cost of this work complete, including tools, boots, and everything, was slightly under $19 per setting, which also included the changing of some services where it was necessary.

We believe that in a place where the services are fairly close together one foreman could handle about six meter setting gangs with the necessary hole diggers and could set about 150 meters per week, providing that everything is thoroughly planned ahead.

Renovating Water Meters

Water Companies, on the whole, and also several of the more progressive municipally owned Water Departments, have found that a little dressing up of overhauled meters before returning them to the customers' service has a desirable psychological effect on the customer. The spray gun and gilt or silver lacquer or a combination of the two is the most universally employed method of dressing up old meters after they have been overhauled and tagged "O.K." on the test bench.

Mr. La Verne Trentlage, Superintendent of Meters in the Water Department of Elgin, Ill., has evolved a scheme which goes the spray-gilting method one better in making "new" meters out of old ones. In the Elgin scheme the metal parts of the meter are given a treatment which removes the oxidized or carbonated coating from the metal and leaves the parts as metal-bright as when turned out by the manufacturer.

Cleaning and Brightening Procedure

(1) Dip meter parts for 10 minutes in *hot* Trisodium Phosphate solution (2½ lbs. or more of T.S.P. in 10 gallons of water).

(2) Remove meter parts from T.S.P. solution and rinse in *hot* water to remove the alkali.

(3) Dip the parts in Muriatic Acid solution (1 part 18 degree Muriatic Acid—to 2 parts of water). Allow to remain in this acid bath for approximately 15 minutes, or longer if necessary. Remove and rinse in hot water.

(4) To brighten to original lustre, immerse in the "bright-dip" solution (1 part 38 degree Nitric Acid, 1 part 66 degree Sulphuric Acid and 1 part water, plus a handful of common salt). Leave the parts in the bright dip for 5 to 10 seconds, the length of time depending on the composition of the metal and degree of brightness desired.

(5) Remove and rinse in *boiling* water to remove acid.

(6) To keep the parts from dulling on standing, a "stabilizing-dip" (especially prepared for this purpose) has been developed by General Chemical Company). After the rinse, the parts are dipped into this solution, removed and allowed to drain and dry.

Notes of Caution: Always add acids to water and *not* water to acids when making dilutions. This will preclude over-heating and spattering of the acid. Be careful to avoid splashing of the acid when dipping the meter parts. In case acid accidentally splashes on hands or face, wash at once in clean water to avoid an acid burn. Spattered acid is also hard on clothing and shoes. Rubber aprons and gloves are good protection.

Do not use iron or steel wire for dipping meter parts. Copper or monel metal wire is satisfactory.

WATER METER TESTING PRINCIPLE AND PRACTICE

[*From "Testing Water Meters—Why and How"*]*

The testing of a water meter is very simple. It consists of checking the registration of the meter against the actual volume of water passing through the meter, as measured in an accurate volumetric tank or weighed on accurate scales.

Meter accuracy may be defined as the quotient obtained by dividing the meter reading by the actual volume of water. Thus a meter registering 9 gallons when 10 gallons are run through it has an accuracy of 9/10 or 90%. A meter registering 52 cubic feet on an actual volume of 50 cubic feet is 52/50, or 104% accurate.

Meter accuracy is commonly expressed in percentage fast or slow. Thus a meter which records 95 gallons when 100 gallons are run through it under-registers or is slow by 5%. A meter registering 102 gallons on the same volume would be 2% fast.

Good Practice in Testing

Before starting a test, water should be run through the meter or meters at a high rate, say 10 or 15 gallons per minute, until all the air is out of the meters and the line, and the delivery pipe to the tank is as full or as empty as it will be at the end of the test. Start the test flow with the test hand of the meter or meters on an even starting position or line on the dial. This can be done either by running water from the outlet of each meter until it has the test hand at the proper position, or the register can be turned around in the case until the test hand stands on the line.

When testing one meter at a time with calibrated tank or with scales having percentage beams, the test flow should be stopped when the meter has indicated the passage of the test amount. The percentage fast or slow of the meter can then be read direct from the tank gauge or from the percentage beam of the scales.

When testing several meters in series or when using scales or tanks without percentage markings, the flow should be stopped when the test volume of water has been run into the tank. The percentage fast or slow of the meter or meters can then be computed by dividing the meter readings by the actual amount of water. It will be seen that the computation will be much simplified if the amount of water is one, ten or one hundred gallons or cubic feet. Thus the divisor is one, which makes the meter reading direct in percentage of accuracy. Example: 100 gallons run through the meter; meter reading 96 gallons; meter accuracy 96%, or the meter is 4% slow.

Amount of Water for Tests

All test amounts except on lowest flow or "sensitive" tests should be at least enough to correspond to one complete revolution of the test hand on the meter dial. Often the test hand pinion is not in the center of the circle on the dial and this would introduce an error in reading with partial turns of the test hand. Common practice is to test on the small flows with an amount representing one revolution and on large flows with an amount representing ten revolutions of the test hand. On the other hand, it is possible to get an accurate test on a ⅝ inch meter with ten gallons or one cubic foot and many meter shops do not go beyond this. Of course the greater the amount of water the smaller would be the errors introduced by inaccuracies in readings.

Single or Series Testing

Meters can be tested one at a time or in series. When there are many meters to test there is a worth-while saving in water and time if several meters are tested at once. The number of meters in series or the number of units in the testing machine justified for any condition depend on the number of meters in the system and the frequency of testing. Testing machines or benches for up to 12 meters are in common use.

In series testing the flow can be stopped when the correct amount of water has been run through the meters into the tank, and the accuracy of each meter computed as indicated above. When only a few meters are tested in series it is possible to take advantage of the percentage calibration on the tank or scales by turning off the water when the fastest meter shows a registration of the test amount, reading the percentage accuracy of the meter, starting the flow again and stopping for each meter as it comes up to the desired reading. This method of obtaining the meter accuracy is not considered good practice as it involves changing the rate of flow for every start and stop involved.

Testing with Test Meters

For testing in the field the so-called test meter is convenient and satisfactory if only a rough check is desired. However, a test meter is only a meter and subject to the same variation in accuracy which is characteristic of all disc meters.

Further, a test meter is not positive in the same way as a tank or scales. Testing one meter with a test meter or with any other meter is simply comparing meters and is not recognized in many states which have regulations or laws applying to means or equipment for water meter testing. Field testing can be done much better and more accurately by means of a calibrated testing tank.

Money Value of Meter Accuracy

The accuracy of a water meter is a matter of dollars and cents to the customer and the utility.

Fortunately for the customers, water meters which were originally accurate cannot over-register beyond a slight speeding up in some water conditions. This action is self-limiting, for friction increases with the building up of the disc or piston and tends to counteract the speeding up. Water meters always slow down in service as they become worn, corroded or encrusted.

The intervals at which it is profitable to the water works to test meters and repair them depends entirely on the effects of the water and service conditions in making the meters under-register, on the value of the water taken but not registered, and on the cost of making the necessary tests and repairs. In other words, if the increased revenue from the meter pays a good return on the cost of making the meter accurate, it is simply *good business.*

Several states have recently adopted regulations which specify limits between meter tests in water utilities, both in time and

*A booklet distributed by Ford Meter Box Co., Wabash, Ind.

MFGR. NO. CO. NO. MAKE SIZE

DATE PURCHASED STYLE

INSTALLATION RECORD **TEST AND REPAIR RECORD**

INSTALLED Date	INSTALLED Reading	NAME	ADDRESS	Tap No.	Reasons for Removal	Removed Date	Removed Reading	Date	Rate of Test Min. Flow	Rate of Test Inter. Flow	Rate of Test Max. Flow	Repairs Before Test	Repairs After Test	Total Amt. of Water Passed Before Test	Tested By	REMARKS

Heading for a Suggested Form for Meter Record Card. This Can Be Adapted to Meet the Requirements of Any Meter Shop. Actual Size of Card Is 8½ by 11 inches.

FORD METER BOX COMPANY

Wabash, Indiana

Products: Meter Boxes, Meter Box Covers, Meter Holding Yokes, COPPERHORNS, COPPERSETTERS, RESETTERS, Meter Testing Machines, Calibrated Testing Tanks, Special equipment for setting and testing water meters.

• • • •

In the correct and thorough testing of water meters it is necessary to be able to set or read the rate of test flow with precision. This is because the accuracy of meters varies with the rate of flow and they must be tested at rates which will show what may be expected at all rates from small leaks and dribbles to full flow. All meter guarantees indicate percentage accuracy at certain rates or within certain ranges expressed definitely in gallons per minute.

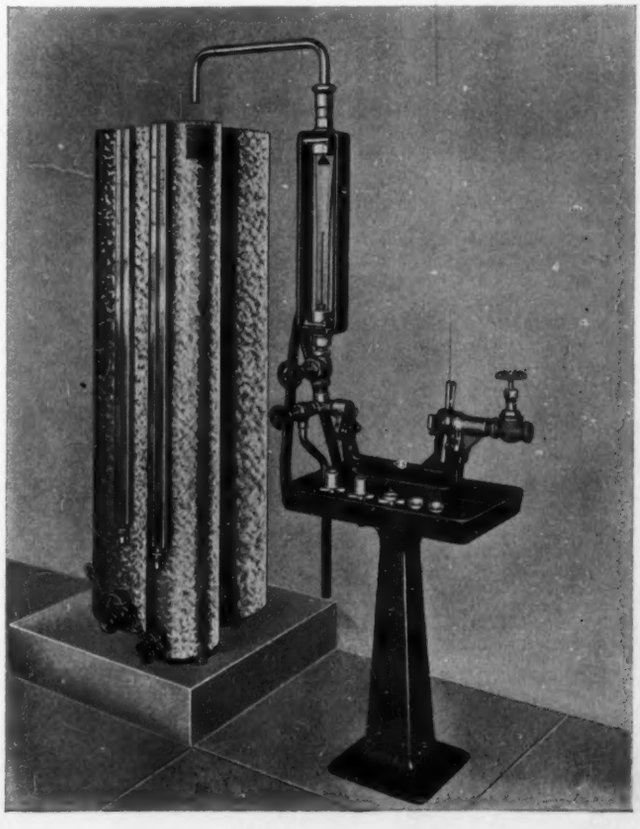
The Testerate Indicator can be connected to any meter tester at the outlet to indicate definitely and accurately all rates of flow from below one-fourth GPM to 35 GPM. This instrument consists of a tapered pyrex glass tube in which a stainless steel rotor is free to move up and down. When water is passed through the tube the rotor rises with the flow until it assumes a position where the space between the tube and rotor permits the passage of the flow. At this point the rotor is supported steadily by the rising stream, rotating freely and in contact only with the water. The exact rate in gallons per minute is read from the etched figure even with the top of the rotor.

As the flow is increased the rotor rises until the space between it and the tapered tube is enough larger to accommodate the greater flow. When the flow is decreased the rotor assumes a lower position where the annular space is less. The position of the rotor depends only on the rate of flow.

METER TESTING MACHINES AND CALIBRATED TANKS

At the right is shown a combination of a No. 1 Ford Tester with Testerate Indicator and with the Nos. 1 and 3 Calibrated Testing Tanks. Ford Testers are made for holding from one to five meters at a time and special machines can be made for larger numbers. All can be equipped with the Testerate Indicator.

Calibrated Testing Tanks are made in four standard sizes and can be made in special sizes. Portable Testing Tanks are made for tests of 10 gallons and one cubic foot. These tanks are simple, accurate and easy to use.



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Write for special bulletin on the Testerate Indicator and for Catalog No. 38 describing Ford equipment for the better setting and testing of water meters.

in volume of water. These limits are necessarily broad, as the composition of water and its effect on meters varies widely in any state, and many utilities profitably test and repair more frequently than required. These regulations show the growing realization that meter testing *is* important.

The following table shows the value of water unregistered by meters of various percentages of slowness, with various amounts of water drawn through the meter and with water valued at from 10c to 50c per thousand gallons. These figures can be easily transposed into cubic ft. by recalling that 100 cubic ft. equals 750 gallons.

From the table it will be seen that with water at 10c per thousand gallons the return on the investment of testing and repairing a meter 4% slow will be only 40c with every 100,000 gallons of water drawn through the meter. It would take a large and active service to make frequent testing pay under these conditions.

On the other hand, with water at 50c per thousand gallons a meter failing to register 20% of the water passing through it (not terribly rare) would lose $1.00 for the water works with every 10,000 gallons. With these conditions maintained accuracy will pay a handsome return on the investment.

TABLE SHOWING VALUE OF WATER NOT REGISTERED BY METERS OF VARYING PERCENTAGES OF UNDER-REGISTRATION, WITH WATER FROM 10c TO 50c PER THOUSAND GALLONS, AND WITH THREE AMOUNTS OF TOTAL DRAFT.

	Value of Water Per 1,000 Gallons								
	@ 10c			@ 30c			@ 50c		
	Total Volume Drawn—Gallons x 1,000								
%*	10M	50M	100M	10M	50M	100M	10M	50M	100M
4	$ .04	$ .20	$ .40	$ .12	$ .60	$1.20	$ .20	$1.00	$2.00
6	.06	.30	.60	.18	.90	1.80	.30	1.50	3.00
8	.08	.40	.80	.24	1.20	2.40	.40	2.00	4.00
10	.10	.50	1.00	.30	1.50	3.00	.50	2.50	5.00
12	.12	.60	1.20	.36	1.80	3.60	.60	3.00	6.00
14	.14	.70	1.40	.42	2.10	4.20	.70	3.50	7.00
16	.16	.80	1.60	.48	2.40	4.80	.80	4.00	8.00
18	.18	.90	1.80	.54	2.70	5.40	.90	4.50	9.00
20	.20	1.00	2.00	.60	3.00	6.00	1.00	5.00	10.00

*Under-Registration Percent.

Steps in Testing a Water Meter

[A ⅝inch meter is used as an example. A larger meter would involve the same procedure but would require greater rates of flow.]

1. **Insert Meter in Tester**—Any means of connecting the meter water-tight in the test line is satisfactory but a regular tester is much more convenient.

2. **Flush Meter Out With a Large Flow**—This is to remove air from the meter and line. A flow of ten or more gallons per minute is desirable and should be continued until discharge indicates that all air is out of the line.

3. **Bring Test Hand of Meter to a Mark**—This can be done by stopping the water flow as the hand reaches the mark, or by turning the dial in the meter case if the meter bonnet is removed.

4. **Run a Test at 10 to 15 G.P.M. Running 50 Gallons or 10 Cu. Ft.**—It is desirable to run this much water although more would be just as good or better. Be sure the calibrated tank is empty or the scales balanced before the test flow is started.

5. **Run a Test at 1 to 2 G.P.M. Running 10 Gallons or 1 Cu. Ft.**—Here again the exact amount is subject to variation and more water can be run if there is plenty of time and water.

6. **Run ¼ G.P.M. Test, Running at Least 5 Gallons or ½ Cu. Ft.**—This low-flow test is important for reasons mentioned on pages 9 and 10.

7. **Make a Record of the Tests**—Put down in permanent form the accuracy of the meter at the three rates of flow, date of test and other pertinent information. See suggested record card on the reverse of this sheet.

IMPORTANCE OF TESTING DISC METERS AT THE CORRECT RATES OF FLOW*

By P. S. WILSON[1]

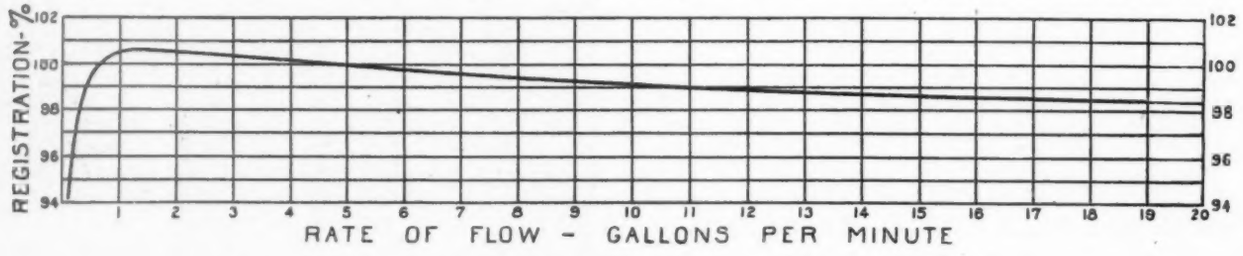
Glen Ridge, N. J.

A typical registration curve of disc type water meters is shown. In this curve the percentage of the water actually registered during passage through the meter is plotted against the rate of flow in gallons per minute.

The curve as a whole may be shifted upwards or downwards by altering the gearing of the meters but this will not change the general shape of the curve. The curve shown in the figure is drawn for five-eighths inch meters but the corresponding curve for any size of disc meter will have much the same shape in relation to the total range of capacity of the meter. The important fact to observe regarding this curve is the fact that it is a curve and not a straight line. In other words, even above the low flows which the meter will not register, the percentage registered is not the same at different rates of flow.

Importance of Testing at Several Rates of Flow

The purpose of testing a meter is to determine the percentage of the water passing the meter which is registered by it. As explained above, this percentage is normally different at different rates of flow. In routine meter shop practice it is of course impractical to test a meter at every rate of flow under which it will actually operate, and yet we must have assurance that it will register within the limits of accuracy adopted at all of these different rates. We know that a test at a single point on the curve, that is, at a single rate of flow, will not give us the percentage registered at other rates of flow. The curve may be of different curvature depending upon the condition of the meter, and we are making the test because we do not know the condition of the meter. If the clearances in the disc chamber are too great, for example, the meter will not register the low flows well and its curve will drop off too rapidly at that end. If the "control" is not close enough, that is, if the spindle is not held at the proper angle, the meter's registration curve will in all probability go up too high at the intermediate rates of flow. With the multiplicity of parts in a



Curve Showing Accuracy of Meter Registration at Variable Rates of Draught

meter there are of course many other defects which may have various effects upon the performance of the mechanism as a whole.

The endeavor must be to test the meter at the least number of rates which will serve to indicate with sufficient reliability what the performance will be over the rest of its range of capacity. It has been found that in normal practice it is necessary to make a test at each one of three different rates of flow, unless the condition of the meter is already quite well known. In order to obtain reliable information from as few as three different rates of test these rates must be carefully chosen in order to show up the true form of the curve and to know that there are no irregularities in it between the points located by the tests.

The three rates of flow at which a disc meter should be tested are usually termed the "Low" or "Minimum" test flow, the "Intermediate" or "Medium" test flow, and the "High" or "Full" flow.

Minimum Flow Test Requirements

The "Low" or "Minimum" flow test is made in order to determine that the meter does not drop off in registration at any higher rate of flow than economically possible, in other words, the meter must be able to register down to a certain predetermined low rate with sufficient accuracy. The accuracy of registration at low flows depends to a large extent upon the reduction of clearances and at the same time the avoidance of friction in the meter.

The rates of flow called for as "Minimum Test Flow" in the Standard Specifications for Disc Type Meters as adopted by the American Water Works Association and the New England Water Works Association, and reproduced herewith as Table I, are the rates of flow in common use. Different organizations vary somewhat the required percentage of registration at these flows to suit individual views and conditions. The Standard Specifications referred to call for at least 90 per cent registration at minimum test flows. Good manufacturing methods and skillful repair work can be considerably better than this on both new and repaired meters, 94 per cent or 96 per cent being not unreasonable to expect.

TABLE I

Rates of Test Flow. From Standard Specifications for Cold Water Meters, Disc Type, Adopted by the A. W. W. A. June 19, 1921, and by the N. E. W. W. A. Sept. 14, 1921

Size of Meter (Inches)	Normal Test Flow Limits (Gallons per Minute)	Minimum Test Flow (Gallons per Minute)
5/8	1 to 20	1/4
3/4	2 to 34	1/2
1	3 to 53	3/4
1 1/2	5 to 100	1 1/2
2	8 to 160	2
3	16 to 315	4
4	28 to 500	7
6	48 to 1000	12

Intermediate Flow Test Requirements

The Intermediate test flow should be chosen so as to ascertain that the registration at the high point of the curve does not go too high. The rates should, therefore, be such as to aim for the probable highest point. This will vary with different makes and types of meters but it will usually be found at, or a little higher than, the lower figure given under "Normal Test Flow Limits" in the Standard Specifications—see Table I. For a five-eighths inch meter the table gives 1 gal. per min. and the test flow should usually be from 1 to 2 gal. per min.

If the meter is geared and fitted so as to maintain a good registration at the low and high flows then the difficulty in most cases will be to keep the registration down at the intermediate flow. The flatter that the curve for the meter is, the less need there is for such practice. This is one of the many things to be considered in selecting a meter.

High Flow Test Requirements

The high flow test is considered by some to be the least important. This is unfortunate because it is the quickest and most convenient to perform. The exact rate of flow to be used at this test certainly is less important than with the low and intermediate tests because at rates of flow above the intermediate the curve is not apt to rise or fall so markedly. Many shops use a high test flow equal to the higher figure given under "Normal Test Flow Limits" in the standard specifications (Table I). For a five-eighths inch meter the 20 gal. per min. flow is approximately the maximum rated capacity of the meter. The practical objection to using this figure for the high test flow is that in very few cases will the service pipe and plumbing in a residence pass nearly so high a rate of flow and we are therefore testing at a rate beyond that at which the meter will ever operate. Between 50 per cent and 75 per cent of this high figure is a more logical one to use for testing in routine procedure. At the high flow the percentage registered should again be kept up, as in the low flow, and a minimum of 98 per cent is often specified in accordance with the standard specifications.

Having given consideration to the reasons for choosing each one of the three different rates of test flow it is of course self-evident that it is of equal importance to actually perform the tests at those rates, in other words, to measure with reasonable accuracy just what the rate of flow is during the test and to adjust it to the correct figure.

TABLE II

Discharge of Orifices in Gallons Per Minute. The Smaller of the Two Figures Given in Each Case Is the Discharge of a Sharp Edged Orifice in a Thin Plate. The Larger Figure Is the Discharge with Properly Rounded Edges

Size of Orifice—Inches	Pressure—Pounds Per Square Inch 40	60	80	100
1/32	0.11— 0.18	0.13— 0.22	0.16— 0.26	0.18— 0.29
1/16	0.44— 0.74	0.54— 0.90	0.62— 1.0	0.70— 1.2
1/ 8	1.8 — 3.0	2.2 — 3.6	2.5 — 4.2	2.8 — 4.7
3/16	4.0 — 6.7	4.9 — 8.2	5.6 — 9.4	6.3 —10.5
1/ 4	7.1 —11.8	8.7 —14.5	10.0 —16.7	11.2 —18.7
5/16	11.1 —18.5	13.6 —23.	15.7 —26.	17.5 —29.
3/ 8	16.0 —27.	19.6 —33.	23. —38.	25. —42.
7/16	22. —36.	27. —44.	31. —51.	34. —57.
1/ 2	28. —47.	35. —58.	40. —67.	45. —75.

Importance of Accurately Measuring Flows

The most frequently used means of determining the rate of test flow is with an orifice. No fault can be found with this means if we really know how much water is flowing through the orifice.

The rate of flow through an orifice of a given size depends principally upon the shape of the edges of the hole, the thickness of the plate in which the hole is drilled, and upon the effective pressure acting to push the water through the hole. Rather than to state the size of the orifice it is far more definite to give the rate of flow in gallons per minute, or as the number of seconds to pass one cubic foot, as is done in up to the minute shops.

Table II gives the uncertainties of using orifices which have not been actually tested under fixed and known pressures. For example, a one-sixteenth inch orifice under a pressure of eighty pounds per square inch may discharge as much as one gallon per minute if the inner corners of the hole are properly rounded. On the other hand if the edges of the hole are sharp and square and the plate through which the hole is drilled is thin the discharge may be less than two-thirds of a gallon per minute under the same pressure. Variations in the effective pressure added to the above uncertainties will of course cause even greater indefiniteness in the discharge. At forty pounds per square inch the discharge of the one-sixteenth inch sharp edged orifice may be considerably less than one-half gallon per minute, while an increase of the pressure to one hundred pounds per square inch will produce a discharge through the same orifice with rounded edges of over two and one-half times as much. Such uncertainties as these will greatly nullify the benefits of otherwise careful testing.

The best way to determine that the correct rate of flow is being used is to actually use a watch, and preferably a stop watch, to time the filling of a calibrated can or tank. The test flows should be stated in terms of definite figures, such as gallons per minute, and not in terms of the size of the orifice or the number of turns of the valve wheel.

The figures given in Table II are the theoretical figures as to the discharge in gallons per minute of different sizes of orifices under different pressures. The smaller of the two figures given in each case is the discharge with a sharp edged orifice in a thin plate, or with the edges properly bevelled on the outlet side. The larger figure is the maximum discharge to be expected with properly rounded edges on the inlet side of the orifice plate. These figures may serve as a guide in the choice by trial sizes of orifices to be used for obtaining certain rates of discharge. Actual measurement and timing should be employed to check each one, however. It must be remembered that the pressure which is effective upon the orifice will only be shown correctly by a gage located next to the orifice, and beyond the meter being tested, also that the pressure reading must be taken after the flow has become steady and constant.

*From WATER WORKS AND SEWERAGE, January, 1933.

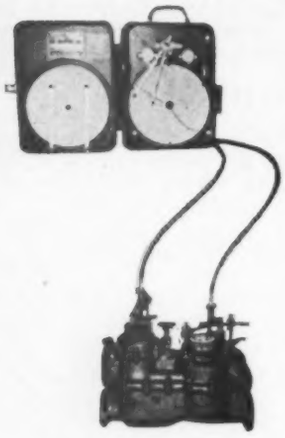
[1]Now Technical Asst. Secy., American Water Works Assn.

F. S. BRAINARD & CO.

246 Palm Street, Hartford, Conn.

The Meter-Master

RATE RECORDER FOR WATER METERS



The Meter-Master was developed in the Water Department at Hartford, Conn., by Distribution Engineer Frank S. Brainard. This instrument soon proved itself to be an indispensable part of the equipment in this department. Demand for similar equipment from other Water Departments throughout the country soon became inevitable. Meter-Masters are now owned and operated by water companies throughout the United States and are meeting with the same degree of success as the original instrument at Hartford.

SATISFY YOUR CUSTOMER

Your customer complains that his bill is too high, he could not have used so much water. You know the meter is correct.

What will you do about it? Have a man spend half a day or more looking for leaks and trying to persuade the customer that the water actually was used.

Or attach a Meter-Master for twenty-four hours and then show the customer the complete record of the amount and time at which water was used. If any of his fixtures or equipment are using more water than they should, you can tell him where the trouble is. If there is a leak, it will be clearly indicated.

The 72-Hour Clock Speed can be used to advantage over week-ends and where longer records are desired. It is sometimes inconvenient to enter premises during the week-end to change the chart each day, but with this speed no attention is required for three days.

SAVE MONEY

You know that you lose money through over-size meters. How can you prevent this loss?

You can pay a man to sit by the meter with a stop watch to record the rates of flow, or you can estimate what the water requirements will be, having a list of fixtures and knowing the probable rates of flow through them. The first method is expensive and neither method has proven satisfactory.

Or you can attach a Meter-Master, using the six-hour clock, and get a complete record of the rates of flow. You save money by using a smaller properly sized meter, through lower cost of the meter and you increase your revenue by reducing slippage.

The value of a "Satisfied Customer" cannot be measured in dollars and cents, but the saving, by eliminating "over-size meters," will make a good showing on the credit side of the ledger.

The Meter-Master has been in use for several years and has proven satisfactory to all Water Departments using it.

TYPES OF INSTRUMENTS

1. The 6 and 24-Hour Round Chart Instrument is preferable for all around use by the smaller departments, using the 6-Hour rate for obtaining peak loads and the 24-Hour rate for general investigations and complaint work.
2. The 24 and 72-Hour Round Chart Instrument is preferable for general investigations and complaints, using the 72-Hour rate when records for more than 24 hours are desired and over week-ends.
3. The Strip Type instrument with its great range of chart speeds may be used for all kinds of investigations.

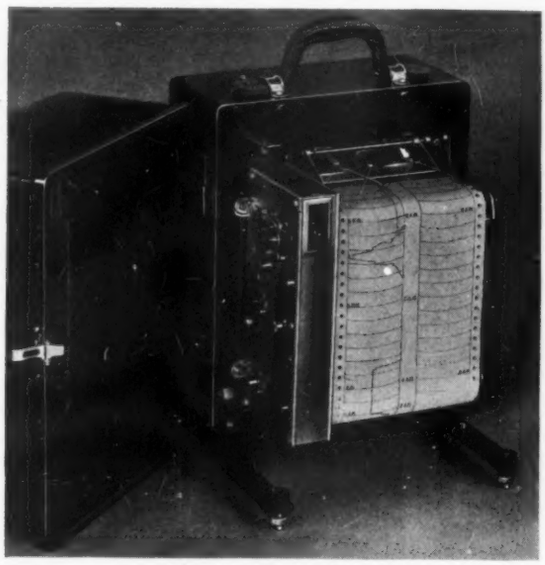
A HANDY INSTRUMENT

Can be attached to ANY meter, single or compound, in five minutes.

Does not interrupt the meter record through disturbance or removal of the meter clock.

Is readily portable, weighing only SEVENTEEN pounds.

Requires no batteries for operation.



THE STRIP CHART INSTRUMENT

This instrument is equipped with a six-speed clock from which chart rates of one, three and six inches per minute or one, three and six inches per hour may be obtained. With this range in chart speeds and a standard chart length of 90 feet it is possible to obtain nearly any desired record. When the chart is progressing at the rate of six inches per minute it advances 1/10th inch per second, making rates per second directly available.

When long periods of flow are being studied it is possible to use the strip chart type instrument to great advantage. A 45-day record, without interruption, may be obtained by operating with a chart speed of one inch per hour.

REDUCER

We have developed a Rate Reducer for use with these instruments when connected to a meter equipped with a Straight Reading Register having a test hand only, to which the Meter-Master may be connected.

Rate Reducers are not necessary with Round Reading Registers as connection may be made to a slower pointer if the test hand revolves too fast for a proper record. Rate Reducers have a ratio of 10 to 1, causing one oscillation of the pen arm to 10 revolutions of the meter pointer. These reducers may be used in tandem, giving a reduction of 100 to 1.

RECORDED WATER WASTE

Some Work of the Water Works G-Man in Settling Complaints

By ROGER W. ESTY, Superintendent

Danvers Water Works, Danvers, Mass.

One of the perplexing problems to handle in a water works plant is the customer who comes in and kicks about the large meter bill that he has just received. Of course, he argues that it was impossible for him to use that amount of water. The meter must be wrong. He requests that it be taken out and another put into its place.

We try to place ourselves in his position and just imagine for a few moments that we have received a bill that perhaps amounts to $9.00. Naturally, if we had been receiving a bill for from $3.00 to $5.00 each month and then this big one came in, we would be upset. Whether he is right or wrong, when he approaches the window to register his protest, he argues in a disagreeable tone of voice to the poor girl behind the counter.

In the olden days after a lot of arguing by both parties, pro and con, the customer left in a huff vowing his vengeance on the poor water works girl or official. Today, when we receive the same kind of customer we agree with him that the bill is high, in fact all out of proportion to what he has been accustomed to paying. Then we compare with him previous readings of his meter during a similar period, and question him carefully and as diplomatically as we can. If, then, we do not determine satisfactorily, to the customer as well as ourselves, the cause or reason for the bill, we then call in the "G-Man" of the Water Department.

What Is This G-Man?

What, or who, is this "G-Man"? Well, this is a nickname given to a machine that really ferrets out and records what is going on at the house of complaining customers. Its real name is "The Meter Master." It is a device which perhaps is about three years old, and is the result of the conception and ingenuity of a real New England water works man, Frank S. Brainard, of the Water Bureau, of Hartford, Connecticut.

While there have been devices that have done this work in a similar manner, it remained for Mr. Brainard to perfect an instrument that registers on a chart the total consumption and the numerous times the water is used during a given period. It is so flexible that it can be connected to any type or style of consumer meter without disturbing the recording device of the meter.

This recorder is operated by a clock mechanism which can be so regulated, that one revolution of the chart is made in 6 hours or in 24 hours. The charts are arranged with an inner and outer circle so that either the reading of a single dial meter (like an ordinary house meter) or two readings may be registered simultaneously, such as is required for a compound meter.

The accompanying picture shows the registering device and the cables that extend to and connect to the register of the meter. It can be used on either a single or a compound meter. Although the charts can be run to secure records for six hours or twenty-four hours, for general purposes it is far more desirable to use the twenty-four hour chart. Only in cases of extremely large flows, or in district testing, is it more satisfactory to use a six-hour chart.

If the meter is the ordinary house type then the first index hand would register 1 cu. ft. As the meter register hand makes one complete revolution (indicating that 1 cu. ft. of water has been drawn) the arm of the recorder makes a stroke up and down on the chart. The first index hand can also be set to register 10 cu. ft. when making one complete movement up and down. This, however, has to be done on a round reading register. It can not be thus used on a straight reading register. The complete record of rates of use, as well as total consumption, is shown when the chart makes a complete revolution in the period selected—6 or 24 hours.

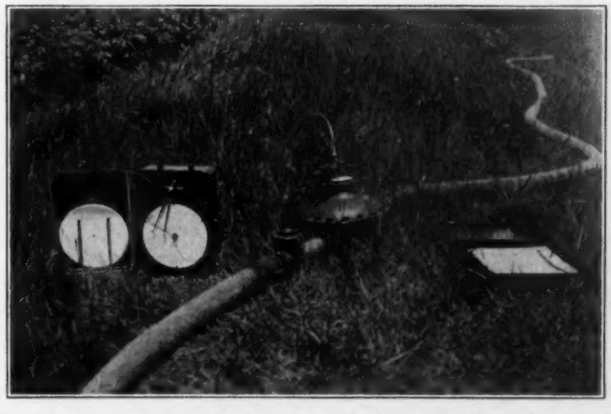
In making tests, the meter cover or cap is removed and a cap ("cartridge," so called) is placed over the first index hand of the meter register. Then a holder, fastened by cap screws, is placed on top of the meter. This holds in place the flexible cable which connects the recording instrument of the "Meter-Master" to the meter. If a compound meter is to be tested, then two cables are utilized, one to each register.

Some Experiences

In order that those who are not familiar with the machine, and its value to the water works superintendent, may get a better conception of its usefulness, I will cite several instances where it has revealed conditions on a service that the ordinary inspection and meter test would not pick up. Then the reader of this article will, perhaps, be more familiar with the advantages that this machine has over any other means of detection work that we have knowldege of.

First, a Simple Case. The customer complains about the size of his bill. He says it is impossible to use so much water, and he says that there are no leaks. We go to his place. He has five overnight camps. We inspect them and find a toilet leaking in the first camp. He says it doesn't amount to anything. We connect the Meter Master to the meter and run a twenty-four-hour test. Total registration 20 cu. ft., 16 cu. ft. of this proving to be leakage. This (at 20c per 100 cu. ft.) amounts to $2.88 for the three months. Results? The customer admits his error, is pleased with the recorded chart, and thanks us with a smile for conducting the test.

The "G-Man" Connected to Meter in a Pit. In Case of Rain Covered with a Dog House.



The Meter Master and Meter Hook-Up in 24-Hour Testing for Consumption and Leakage on a Section of Main.

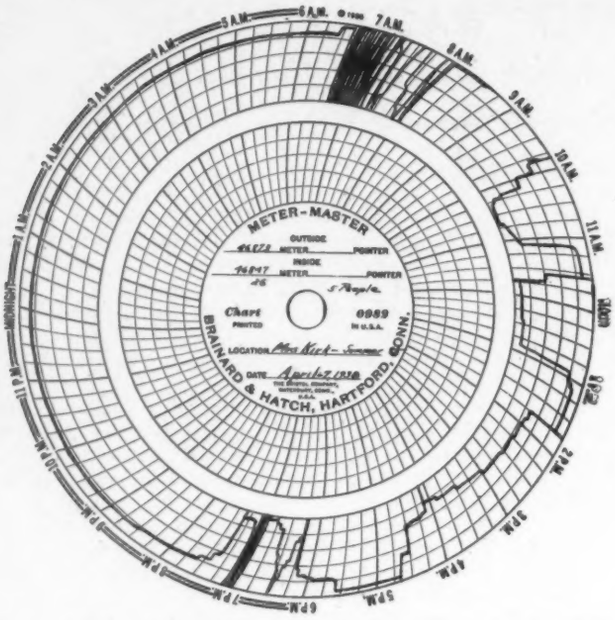


Fig. 1. An Interesting Chart. It tracked down water waste at 6:40 A. M. (13 cu. ft.) and again at 6:55 P. M.—Trouble: a toilet tank that would keep running at times unless the handle was flipped. In another case the same thing happened four times. In another, this leakage was at a slower rate and would run undetected from bed-time to morning. To the consumer "seeing is believing."

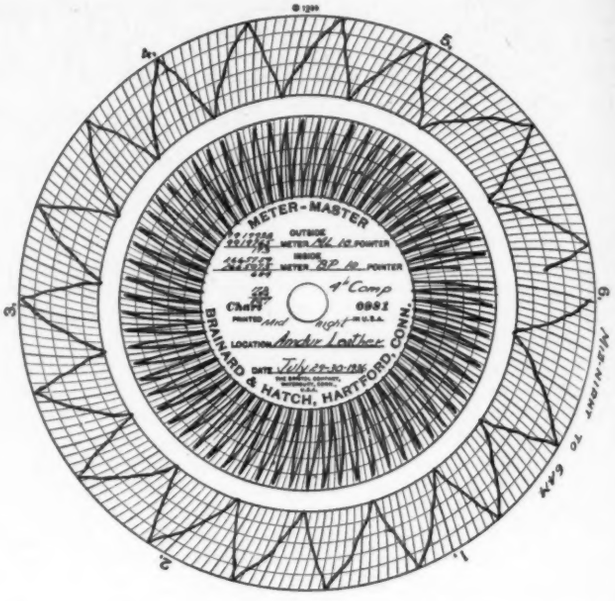
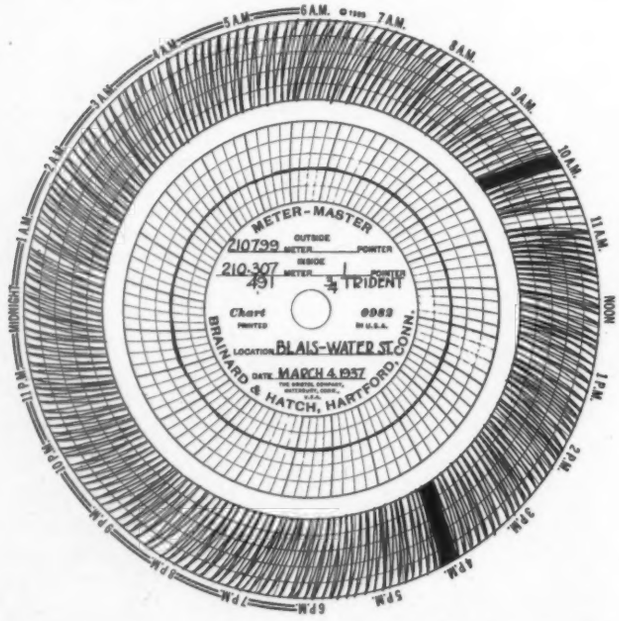


Fig. 2. A Splendid Six-Hour Chart. A 4-inch compound meter working at an industrial plant from midnight to 6:00 A. M. This shows how important it is to have good meters and registering 100% —857 cu. ft. recorded, = avg. of 18 g.p.m.

Another Case. Two houses on one meter. Owner and wife in front house. Young couple and three old people over 70 in second house. Bill about $9.00 per quarter. We found by the chart reading that water was being used some time during 23 of the 24 hours. All during the night toilet flushings were indicated on the chart. We assumed, and since have been convinced, that this night consumption was caused by these old people. No more complaints from this customer. He had a true picture of just what is going on at his house all of the time.

Third Case. Two houses on one meter. Two families in front house and one in the rear. Bill about $12.00 per quarter. We found that on five different occasions four cubic feet of water was used. This amounts to 30 gallons. We questioned each family as to their habits and found that the family in the second house were the cause. Their hot water storage tank, back of the kitchen stove, got so hot it would rumble. The lady of the house would open the hot water faucet and let it run



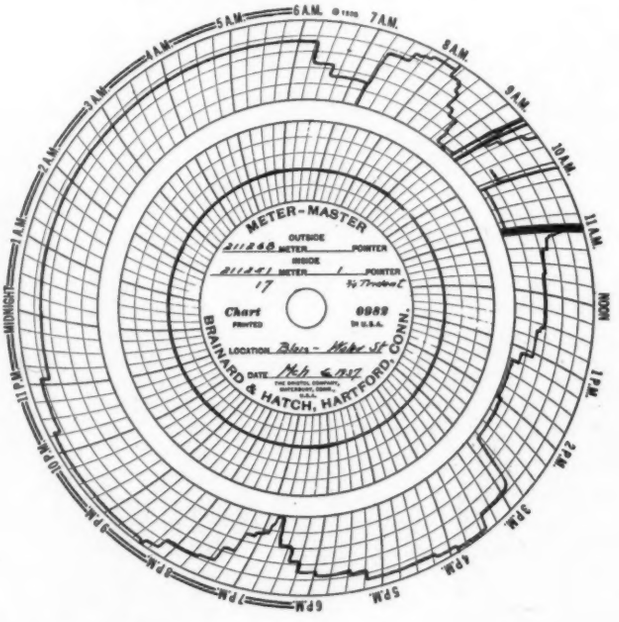


Fig. 3. Specimens of Before and After Charts.

Here a ¾-In. Meter Was on a 2-In. Line about 1,200 Feet Long. A Pin Hole Leak Developed and in 24 Hours the Meter Registered 491 Cu. Ft., or 2.9 Gallons Per Minute. After the Leak Was Repaired, According to the Check Chart, the Consumer Used Only 17 Cu. Ft. in 24 Hours. Quite a Convincing Story to This Customer, and Also Quite a Saving to Him.

On the chart made before repair the actual number of swings of the recording pen was approximately twice the number shown here, the chart having been redrawn in this manner for the sake of clearer reproduction.

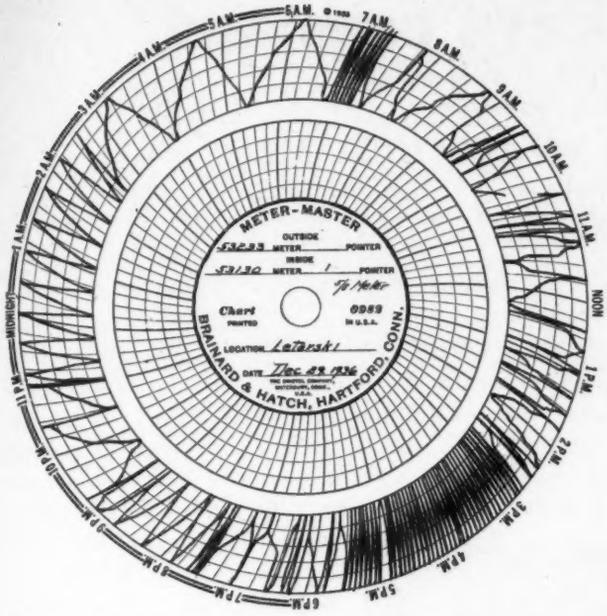


Fig. 4. A Genuine "G-Man" Chart. This was on a two-family house. Between the hours of three and five the lady upstairs was doing her washing in running water. (See text.) The bill was running $13.90 on an average, but since discontinuing this practice it is now $5.20 per quarter. Some expensive washing.

off, until it became cool, and then shut it off. This would cool it down for several hours. The cause? They had two small copper coils around the two oil burners in the stove. They were around the top of the burners and, consequently, received all of the heat. I suggested lowering the coils half way down on the burner. It has eliminated the high meter bill. This wouldn't have been discovered in any ordinary fixture inspection and, possibly, by no amount of questioning.

Fourth Case. A two-family house, and a bill of $12.00 per quarter. From the meter charts we found that on occasions, from one hour to as long as three hours, a continuous stream was running. We ran this test for three days, as it was so unusual. An inspection on one of these occasions immediately located the cause. A family of two adults and three children occupied the second floor of this tenement. The lady of the house placed her washing in a set-tub and then turned on the faucet and left the water running while she did the house work. In ten or fifteen minutes she would come back, work the garments around in the water and go off about her work again. This was kept up until the washing was completed.

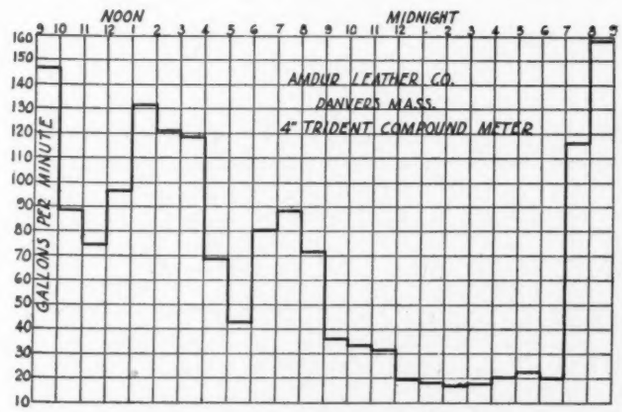


Fig. 5. Hourly Consumption Graph. Plotted from 6-hour meter master charts, on a compound meter, covering two full days of recording, but shown here as the average for a single day. The minimum and maximum draft rates are especially useful in determining the proper type of meter to employ, etc.

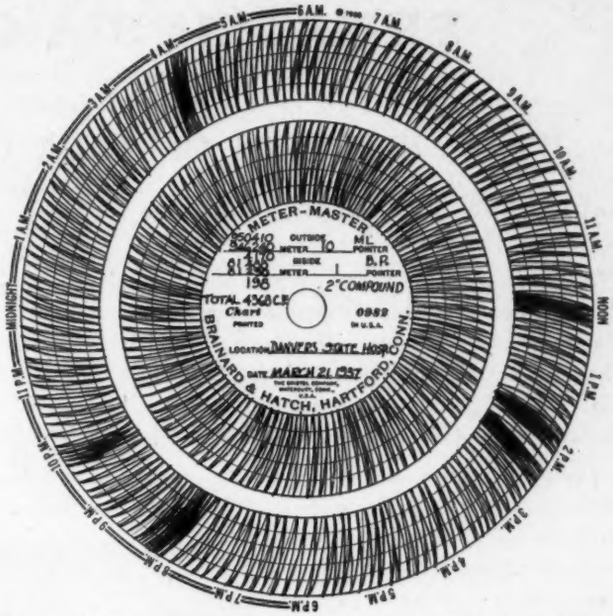


Fig. 6. Revealing a Steady Flow Through a 2-Inch Compound Meter. This chart changed our mind as to the type of meter that should be on this service.

The actual number of swings of the recording pen was approximately twice the number shown here, the chart having been redrawn in this manner for the sake of clearer reproduction.

Applications Are Several

The value of this testing and recording device is two-fold: First, to run flow tests on services to find out how often and at what rate the water is drawn. This, in order to determine whether the meter is too large or too small for that particular service. We have also operated at the same time a pressure recording gauge and this will record the drop in pressure when the water is drawn. Secondly, to check large or out of the ordinary meter bills. In this case it provides visual evidence of exactly how much water is used and when, and thus gives the customer an actual picture of his consumption demands. In addition, it furnishes information regarding the presence of leaking fixtures, the use of improper amounts of water by toilets and other possible sources of waste.

The rate recorder has been used in conjunction with flow tests on large meter installations to determine when heavy demand occurs and at what rate the water is drawn. It has a particular value in connection with night flow testing of the distribution system. In these tests the town is divided into districts and supplied through fire hose and in most instances through one 2-inch meter. The test is generally started at 6:00 p. m. and continued through the night to 6:00 a. m. Valuable flow data can thus be obtained economically, and without much effort.

Our source of supply is in the Town of Middleton, five miles from the center of Danvers. Most of this town has public water service. It is very interesting to study the daily demands of this little town. We serve a population of about 1,200 people in Middleton, through 300 active services on 7 miles of pipe. All services are metered.

The maximum demand, according to the chart, is between the hours of nine and ten in the morning, when they used 52 gallons per minute. The minimum demands come between the hours of three and four in the afternoon, when they used at the rate of 12 gallons per minute. The figures are very conclusive that the system as well as the household fixtures are tight.

The latter is another instance of the use to which this machine can be put. This test only took one day to run, but we changed charts every 6 hours in order to study more closely the variations in the demand for water for an entire town. It only goes to show how little water a small residential town actually requires.

PHILADELPHIA QUARTZ COMPANY

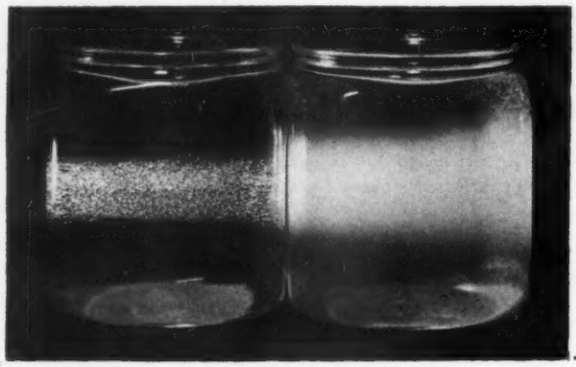
General Offices: 121-129 S. Third St., Philadelphia
Chicago Sales Office: 205 W. Wacker Drive

SILICATES OF SODA FOR WATER TREATMENT

Manufacturing Plants at
Anderson, Ind. Baltimore, Md. Buffalo, N. Y. Chester, Pa. Kansas City, Kans. Jeffersonville, Ind. Rahway, N. J. St. Louis, Mo. Utica, Ill.

WATER COAGULATION: Water supply engineers use PQ Silicate to improve coagulation and filtration, economically and efficiently. If the plant has limited filter capacity or the effluent is turbid, PQ Silicate is a real aid. Also, PQ Silicate is particularly valuable during periods when it is difficult to obtain good coagulation.

Used with alum, sodium aluminate, copperas, chlorinated copperas or ferric sulphate, PQ Silicate produces a larger, tougher floc. The advantage of this is that a higher flow rate thru a sand bed is possible without passing floc thru with the effluent. The higher flow rate can be achieved thru an increase in the effective pressure head on the filters or thru the use of coarser sand. We shall be glad to furnish the correct silicate of soda for your jar tests, and to discuss your individual coagulation problems.



WATER CORROSION CONTROL: The addition of small amounts of PQ Silicate to the water supply eliminates "red water," protects water mains and service pipes. The PQ Silicate method is favored over other treatments because (1) it does not increase hardness (2) it is unnecessary to raise the pH to high values (3) it is not dependent on water analysis (4) there is no danger of getting too thick a deposit.

• • •

Ask for bulletins on both these uses of PQ Silicates in treating water.

Raw untreated water, with same quantity alum added to both jars. Left: Silicate treated. Right: Without silicate. Photographed five minutes after stiring of chemicals ceased.

Experience in Sterilizing New Mains

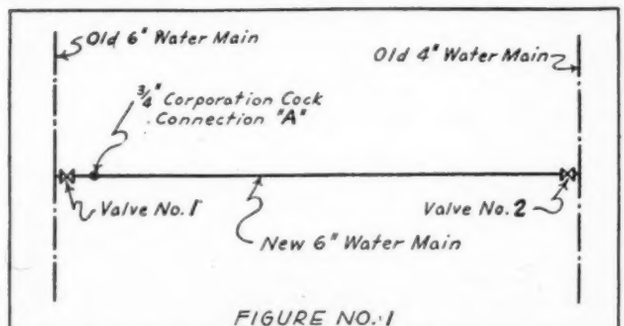
By CARL LEIPOLD

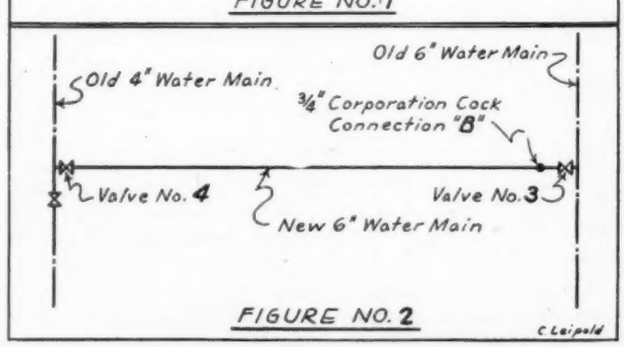
Superintendent of Filtration, Winnetka, Ill.

It was shown by tests made at the time of sterilizing a new pipe line that it is very essential that the water added to the pipe will distribute the applied "H T H" (calcium hypochlorite) uniformly through all parts of the new pipe.

On completion of a new pipe line (Fig. 1) about thirty grams (a heaping handful) of "H T H," representing a treatment of 100 lbs. chlorine per million gallons of water, was applied through a paper funnel placed in the neck of the corporation cock at connection "A" and the pipe was filled with water through valve No. 1. Residual chlorine tests made of the water samples collected from connection "A" after all the air was removed and the pipe was full of water, showed only .10 to .20 p.p.m. of free chlorine. After a chlorine contact period of 3 hours, valve No. 2 was opened and the new pipe line was flushed through connection "A." Residual chlorine tests made of the water samples collected from connection "A" showed a gradual increase of free chlorine and after 30 minutes of flushing the test showed a deep red color. These results indicated that on filling the pipe line, the largest portion of the disinfectant had been carried to the far end of the pipe line near valve No. 2, leaving no chlorine for sterilization at the near end of the pipe line where introduced.

On completion of another new pipe line (Fig. 2) the same sterilizing procedures were carried out as described above with the exception that a different method of filling the pipe line with water was employed. This pipe line was partially filled with water through valve No. 3 and then completely filled with water through valve No. 4. Flushing the pipe line through connection "B" from valve No. 4 was done until the residual chlorine test of the water sample showed a deep red color. It was then closed off. After a chlorine contact period of two hours, valve No. 4 was again opened and the new pipe line was flushed through connection "B." The residual chlorine tests made of the water samples collected from connection "B" showed a gradual decrease of free chlorine and after 30 minutes of flushing the test showed no free chlorine. These results indicated that the "H T H" had been uniformly mixed throughout the pipe line by proper control of the valves.





Illustrating an Effective (Fig. 2) and an Ineffective (Fig. 1) Method of Sterilizing Water Mains

% PROPORTIONEERS, INC. %

9 N. CODDING STREET, PROVIDENCE, R. I.

REPRESENTATIVES IN PRINCIPAL CITIES

PRODUCTS — Complete line of chemical solution feeders and dry feeding control equipment for water and sewage plants, Chlor-O-Feeders for hypo-chlorinating constant rate or variable flow water supplies in proportion to flow. Multiple feeding pump units for feeding one, two, three, or more chemicals. Ferr-O-Feeders for feeding ferric chloride, Calgon Feeders, Portable Chlor-O-Feeders for standby or emergency use. Gasoline driven portable water pumping units with built-in Chlor-O-Feeders. Engineering service on proportioning problems.

CHLOR-O-FEEDERS IN WATER WORKS SERVICE

Midget Chlor-O-Feeders for constant rates. Chlor-O-Feeders definitely led the way to low-cost hypochlorination making it possible to sterilize even the smallest water supply safely, and economically. For plants treating up to 1½ million gallons per day hypo-chlorination is practical.

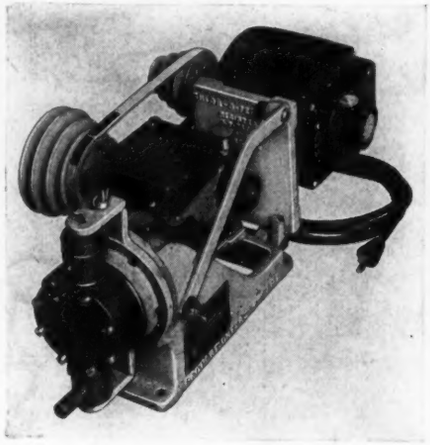


Fig. 1. Midget Chlor-O-Feeder, electric motor driven.

Midget Chlor-O-Feeders (Fig. 1) are furnished for high or low pressure or for feeding into suction side of pump. The device is small; quickly adjusted for different feeds; driven by electric motor, water motor, or by belt connection to water pump drive.

Installation is simple, with aid of instruction book, and operating costs are low as anyone able to operate the water pump is fully capable of running the Chlor-O-Feeder to satisfaction of Health Department.

Portable Chlor-O-Feeders—mounted and ready to operate anywhere on instant notice; or mounted in hand case for carrying in back of car; are ideal for emergency use; as standby to temporarily replace gas chlorinator; for sterilization of new or dead end mains; or to augment other units during periods of extreme demand.

Proportional Chlor-O-Feeders for variable flow rates. For many conditions, especially in gravity systems from reservoirs, where flow rates vary considerably from hour to hour, it is essential that Chlor-O-Feeder be controlled by the flow of water so that the amount of solution injected is at all times in proportion.

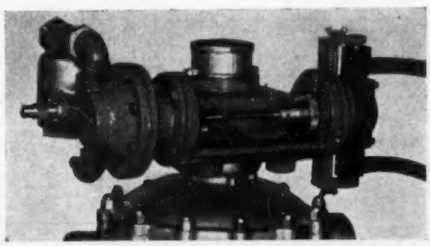


Fig. 2. Proportional Chlor-O-Feeder, meter mounted.

Proportional Chlor-O-Feeder (Fig. 2) can be mounted on and controlled by any flow responsive device; standard water meter of any make, size or type; flow responsive rotor; Venturi Tube; orifice plate; or even the reciprocating parts of deep well pumps can be used to "pull the trigger" that sets off the chlorinating discharge. Chlor-O-Feeder can be operated at any point where the water line can be cut to allow installation of meter. It can be operated entirely by water pressure, so does not require expense of wiring. Operation is simple without the attendance of experts.

pH CONTROL BY CHEMICAL FEEDING

pH control by proportioning lime, soda ash, sodium silicate, sulphuric or other acids, is made simple by use of these flow-proportional chemical feeders. Highly successful installations, designed by leading engineers, are providing permanent relief from plugged and corroded pipe lines.

FERR-O-FEEDER AND CHLOR-O-FEEDER IN SEWAGE PLANTS

Hypo-chlorite sterilization of sewage effluent may be satisfactorily practiced in small sewage plants. Especially suited, too, for CCC camps, summer colonies, and other small sewage systems; chlorinating constantly; manually started and stopped as required; automatically starting or stopping with sewage pumps; or operated, automatically controlled, from sewage syphon. Ferr-O-Feeders feed ferric chloride for treatment of sludge before vacuum filtration; for treating raw sewage, and all kinds of process wastes.

STERILIZING SWIMMING AND WADING POOLS

Public health demands the closest supervision of swimming and wading pools. Triplex Midget (Fig. 3) feeds hypo-chlorite for sterilization —alum for coagulation — and soda ash for pH control; and costs less than the three separate units previously used. In addition to the low cost advantage, the results are better as all three chemicals are kept "in step" with one another at all times.

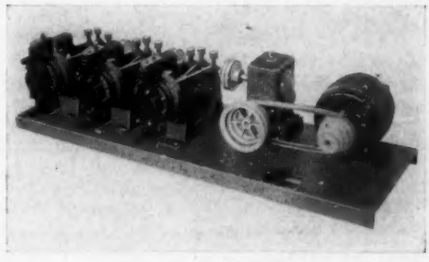


Fig. 3. Triplex Midget Feeder.

ENGINEERING SERVICE ON PROPORTIONING PROBLEMS

Manufacturing feeders for all chemicals and all conditions has enabled %Proportioneers% to acquire valuable experience in this specialized field. This experience is available to you for the asking—correspondence, in detail, is invited.

OMEGA MACHINE COMPANY

4010 Penn, Kansas City, Mo.

PIONEERS IN CHEMICAL FEEDING AND METERING

Advocates of Accuracy and Efficiency

1927 **OMEGA** started with one feeder and a one-man shop. The next year the Universal Feeder was developed, and is still a leader.

1929 **OMEGA** pioneered in the mounting of small feeders on platform scales and large feeders on hopper scales, so that the rate of feed can be regularly and accurately checked.

1931 **OMEGA** pioneered in the development of improved lime slaking apparatus. The first move was to develop better agitating mechanism. This was followed by insulated slakers and thermostatic control of the water supply. Omega is the only manufacturer urging high temperature slaking.

1935 **OMEGA** pioneered in the development of Gravimetric Feeders for controlling the rate of feed of dry and liquid materials by weight and not by volume. Realizing that no single type of feeder was suitable for all sorts of conditions, Omega simultaneously developed two types of Gravimetric Feeders.

The Batch type Gravimetric Feeder has a batch hopper on scales, from which material is withdrawn at a rate controlled by the scale mechanism. It is a very accurate unit and is built with hopper capacities up to 10,000 lbs. and feeding capacities up to 3,000 lbs. per hour.

The Belt type Gravimetric Feeder maintains a constant weight of material on the feeder belt and the rate of feed is controlled by changing the speed at which the belt travels. This feeder is particularly well adapted for medium and large rates of feed and for installation in places where the headroom is low and where batch hoppers are not desirable.

1936 **OMEGA** pioneered in developing and using dust removal equipment to prevent the escape of dust incident to the filling of feeder hoppers, and today is the only manufacturer regularly advocating such construction. Dust incident to the filling of feeder hoppers is a nuisance which can be prevented at small cost.

1937 **OMEGA** pioneered in the construction of volumetric feeders with built-in hopper scales to take the place of the awkward platform scales and overhead hopper scales formerly used to check the delivery from the feeders.

OMEGA pioneered in solution feeders for liquids, particularly in the construction of complete self-contained units without separate solution tanks or jars and other accessories and large feeders for ferric chloride and other liquids. A special feature of the small Omega solution feeders is that they are all equipped with a special gauge by which the exact rate of delivery under operating conditions can be instantly determined. Liquid feeders are made for gravity feed and for pressure feed by an **OMEGA** built-in pump.

1938 **OMEGA** pioneered by simplifying the batch type Gravimetric Feeder to such an extent that the cost is now well within the reach of hundreds of small plants. With these feeders, guesswork in the feeding of chemicals can be eliminated.

1939 **OMEGA** continues to pioneer and to give individual attention to the unusual problems of the designing engineer, involving feeding and **exact** proportioning of chemicals (in dry or dissolved state) in modern water-works and sewerage practices.

In this direction **OMEGA** takes especial pride in its most recent pioneering of import, in having equipped the "World's Fair Treatment Plant—1939"—namely, the Talman's Island Plant of New York City with its chemical feeder requirements. Capacity 3,000 Pounds per Hour — Explosion Proof Electrical Equipment — Complete Dust Removal—Gravimetric Type Feeders.

FIG. 1

Gravimetric Feeder, batch type, with extension hopper. A few purchasers listed below:

Cincinnati, Ohio....10	Procter & Gamble
Augusta, Ga..... 5	Co. 14
Springfield, Ill..... 6	(7 repeat orders)

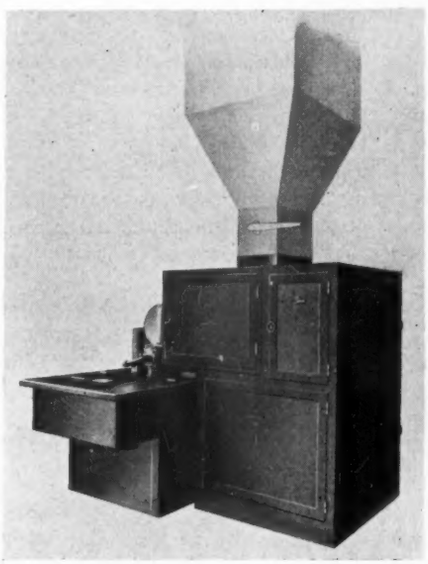


FIG. 2

Gravimetric Feeder, belt type, discharging into an Omega Lime Slaker. A few purchasers of belt type feeders listed below:

Little Rock, Ark... 4	St. Louis Co. Water
Denver, Colo..... 4	Co., St. Louis, Mo. 5
Atlanta, Ga..... 2	(3 repeat orders)

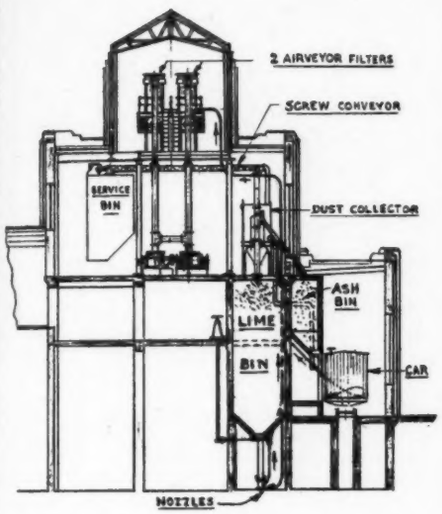
OMEGA is the **only** concern in America engaged exclusively in the manufacture of material metering and feeding devices.

FULLER COMPANY

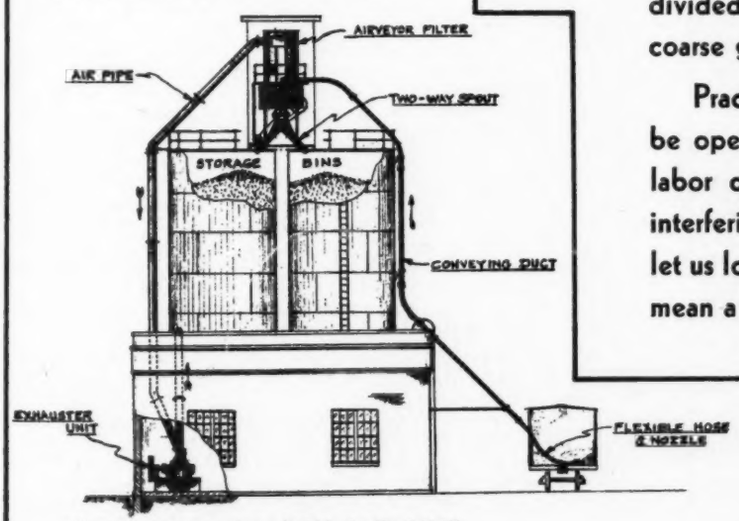
CATASAUQUA, PENNSYLVANIA

Chicago: 1118 Marquette Bldg. San Francisco: 320-321 Chancery Bldg.

The AIRVEYOR



HANDLING LIME AND ASHES

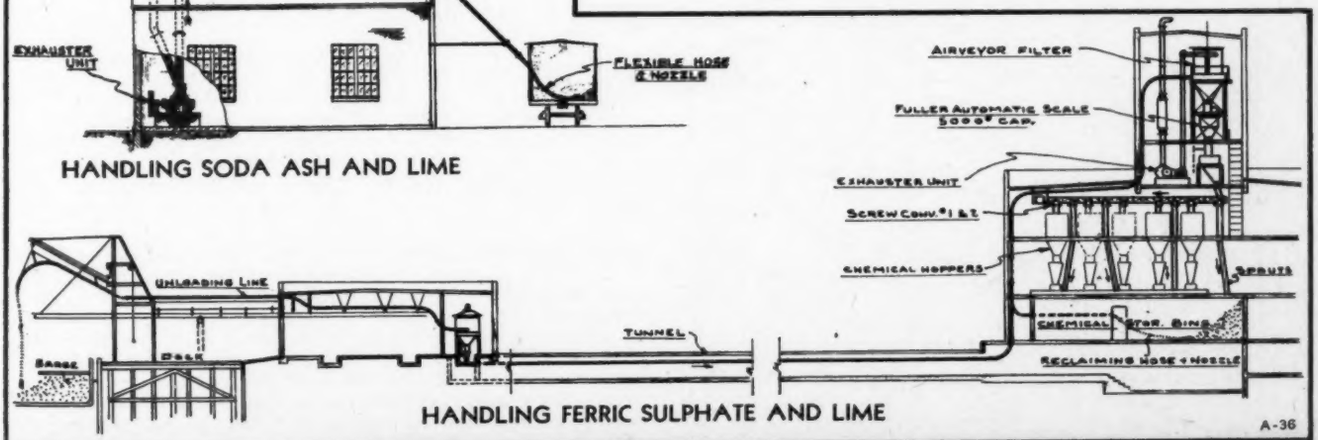


HANDLING SODA ASH AND LIME

CLEAN, EFFICIENT, LOW MAINTENANCE UNLOADING, CONVEYING AND RECLAIMING

THE Airveyor Conveying System is noted for its cleanliness, efficiency and low maintenance for conveying fine, crushed and granular materials. Many of these systems are in daily use. Over sixty different materials are handled, proving its adaptability to many classes of service. It will handle finely divided materials without any dust losses, as well as coarse granular materials.

Practically every Airveyor System installed can be operated by one man, in this way cutting down labor costs. The system can be installed without interfering with your present operation. Why not let us look into your conveying problem . . . it may mean a saving you never thought possible.



HANDLING FERRIC SULPHATE AND LIME

A-36

FULLER-KINYON, FLUXO, AND AIRVEYOR CONVEYING SYSTEMS · · · · ROTARY FEEDERS AND DISCHARGE GATES
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TREATING WATER TO PREVENT CORROSION*

By JOHN R. BAYLIS†

Associate Editor, Waterworks & Sewerage

The writer, in 1930, presented some of the factors involved in preventing corrosion of water pipes.[1] Curves were given to show the solubility equilibrium of iron and zinc compounds in the presence of their respective metals. These curves (Fig. 1) show that practically no iron or zinc will exist in solution when the pH is above 8.0. At a pH of 7.0 several parts per million of either metal may exist in solution in some form in the absence of oxygen, and at a pH of 6.5 quite a large amount of iron or zinc may be found in solution in the absence of oxygen. The article explained how corroding iron took all the free CO_2 and much of the half-bound CO_2 from the water, leaving the water distinctly alkaline where there was no dissolved oxygen present. If the water contained dissolved oxygen the iron was precipitated as a hydrous oxide. Section of a 1-in. cement lined pipe, which had been in service for 50 years at Danvers, Mass., also was shown. The interior of the pipe was in fairly good condition, indicating that the lining was still giving very good protection.

Carrying Capacity of Pipes Greatly Reduced by Incrustation Resulting from Corrosion.—That the carrying capacity of iron pipes may be greatly reduced by tuberculation and incrustation as a result of corrosion is well known to most every one.

Haydock[2] describes how cleaning the tubercles or incrustation from several pipe lines increased the flow. One line carried only about one-half its theoretical capacity, and another about two-thirds. Cleaning a pipe line 3 miles long increased the capacity to the extent that a pumping station could be abandoned, and cleaning another line 5 miles long also enabled the abandonment of a pumping station. The friction loss through a 12-in. line 4 miles long 20 years old was nearly three times that of a new line. The capacity was increased by approximately 35 per cent and the delivered pressure by 20 lb. The gravity delivery of a 16-in. pipe 10.5 miles long was increased 60 per cent by cleaning. Cleaning a 13 mile section of a 12-in. pipe

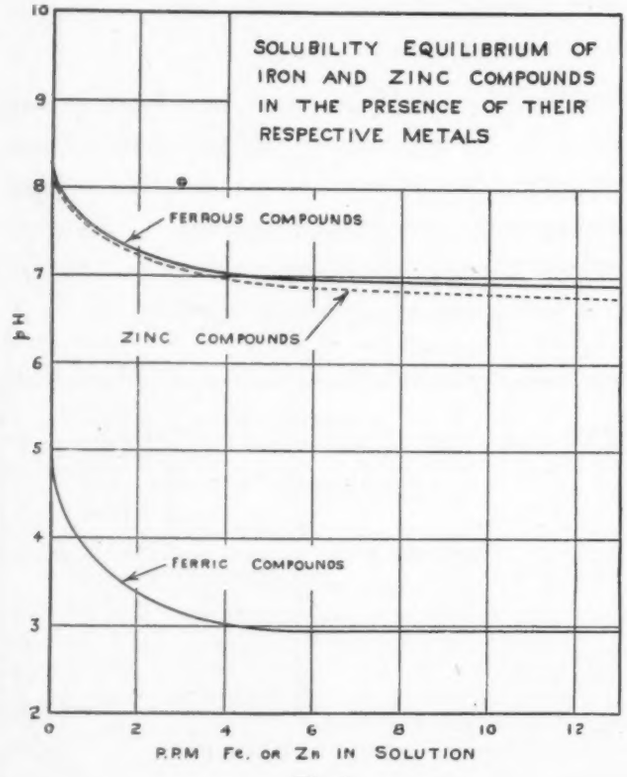
SOLUBILITY EQUILIBRIUM OF IRON AND ZINC COMPOUNDS IN THE PRESENCE OF THEIR RESPECTIVE METALS
FERROUS COMPOUNDS
ZINC COMPOUNDS
FERRIC COMPOUNDS
pH
P.P.M. Fe. OR Zn IN SOLUTION

Fig. 1

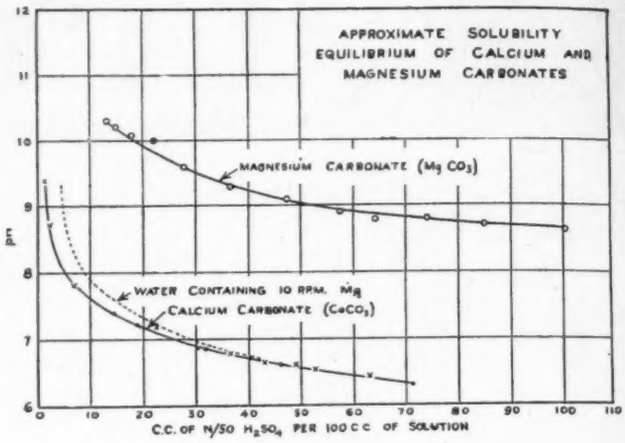
APPROXIMATE SOLUBILITY EQUILIBRIUM OF CALCIUM AND MAGNESIUM CARBONATES
MAGNESIUM CARBONATE ($Mg CO_3$)
WATER CONTAINING 10 P.P.M. Mg
CALCIUM CARBONATE ($CaCO_3$)
pH
C.C. OF N/50 H_2SO_4 PER 100 C.C. OF SOLUTION

Fig. 2

line 22 miles long, which had been in service about 16 years, increased the capacity approximately 35 per cent, and cleaning another section of the line 6 miles in length increased the carrying capacity to 46 per cent.

Increased Pumping Pressure or Larger Mains Very Expensive.—In some instances it is possible to deliver the desired amount of water through distribution systems that have become partially clogged by increasing the pumping pressure as the friction losses increase, or to install booster pumping stations on the distribution system in certain sections where the pressure is low. Haydock refers to the delivered pressure being increased 20 lb. by cleaning the pipes in one instance. Assume that it was desired to maintain this 20 lb. increased pressure, evidently it was quite expensive to do it at the pumping station. A fair average of the cost of lifting one million gallons of water 1 ft. in height is probably 5 ct. Twenty pounds is equivalent to about 46 ft. in head. In this case it would cost about $2.30 per million gallons to maintain the increased pressure.

If corrosion is going to reduce the carrying capacity of the water mains in a certain city 50 per cent within 20 years, what is the best way of handling such a situation? Should mains be installed large enough to give the desired capacity with a 50 per cent reduction in carrying capacity? The cost of such an investment over what would be necessary if there was no corrosion very likely would be much more than the cost of making the water reasonably non-corrosive.

With the exception of feeder mains, engineers usually desi[illegible] the water distribution system for fire protection. How many engineers allow for a 50 per cent reduction in the carrying capacity of the pipes within 20 years where the water is corrosive? How many make any distinction whatever in the design where the water is corrosive and where it is not corrosive? The writer is of the opinion that corrosion has not been given its proper consideration in the design of water systems. This is largely due to the lack of specific information in the past as to how much the carrying capacity will be reduced within a certain time.

Treatment with an Alkali for Partial Protection.—The literature on the treatment of water to prevent corrosion indicates quite conclusively that the corrosiveness of water may be greatly reduced by proper treatment. It seems that some of the authors of articles on corrosion prevention do not fully realize the importance of a film for protection. So long as iron stains are prevented, some think that this is all the treatment that is necessary. As a matter of fact the carrying capacity of the pipes may be reduced just as rapidly as before, because most of the corroding iron is deposited near where the corrosion is taking place and forms large tubercles that are more effective in reducing the carrying capacity of the pipes than if the rust was

*Excerpts from an article which appeared in WATERWORKS AND SEWERAGE.

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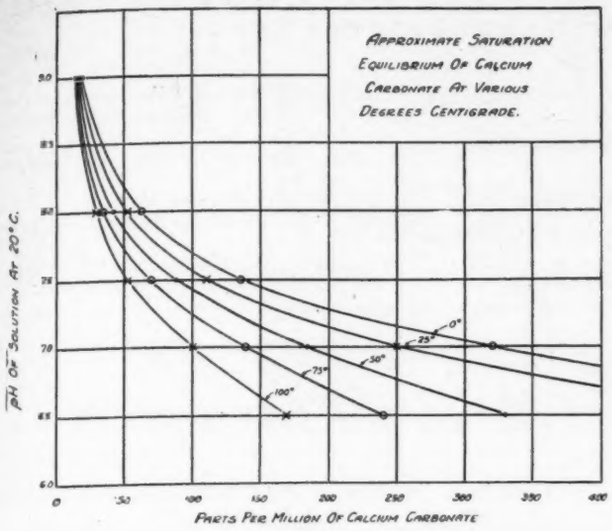

Fig. 3

deposited fairly uniform over the surface of the pipe. Treatment just to the point where red water complaints cease may not materially reduce the cost to the water department for cleaning pipes, constructing new mains, and increasing the pumping pressure.

Water Just Saturated with Calcium Carbonate s the Most Desirable Equilibrium.—As a general rule, it might be said that water saturated with calcium carbonate is the most desirable equilibrium when everything is taken into consideration. This is not strictly true for very soft waters, for it is desirable to have the water slightly supersaturated part of the time so as to form a thin protective film. Where the calcium carbonate alkalinity of the water is below 30 parts per million the application of lime to produce a slight supersaturation of calcium carbonate should be done with considerable care, otherwise caustic water might be produced. After a thin coating has been formed on the pipes the water should be kept saturated with calcium carbonate practically all the time to keep the coating from being dissolved. It is admitted that the very soft waters are the most difficult to protect, for we are working with equilibriums difficult to maintain exactly on the saturation point. It may be almost impossible to do this with the force available in small plants and it may be necessary to sacrifice some protection to avoid occasional caustic taste in the water. There is no reason why large plants with skilled supervision should not be able to maintain a fairly constant equilibrium.

Table I—Rapid Increase in pH Caused by Corroding Iron

Alkalinity	Time in Contact with the Iron Minutes	pH	Fe in Solution
39	0	7.2	
	1	7.3	
	2	7.4	
	3	7.7	
	5	8.2	
	10	9.2	
	15	9.4	
35	20	9.6	0.0tr

Where water has a calcium carbonate alkalinity in excess of about 30 it is easier to protect the pipes. If this water is placed in contact with an iron surface the iron going into solution will take up all the free Co_2 that is in the water and part of the half-bound CO_2. Table I shows how quickly the pH changes in water exposed to iron lathe turnings. After the pH reaches 8.1 no free CO_2 is present. This was due to the CO_2 combining with the corroding iron.

At any point on the surface of an iron pipe where corrosion starts to take place due to the surface becoming exposed in some manner, there is a tendency for the iron going into solution to take up the free and part of the half-bound CO_2, producing a supersaturation of calcium carbonate in the immediate point where corrosion is taking place. This supersaturation helps to quickly form a coating over the exposed surface both by precipitating the iron compounds and also some calcium carbonate, especially when the water has a fairly high alkalinity. If the water in the mains is saturated with calcium carbonate, then the precipitated calcium carbonate will not be dissolved out of the percipitate. It will remain where it is precipitated to offer protection against further corrosion.

Most natural waters contain magnesium carbonate as well as calcium, and the presence of a considerable amount of magnesium may materially alter the equilibrium curve. This is shown by the curves in Fig. 2. The presence of sodium carbonate also alters the curve. When sodium carbonate is present the only way the saturation equilibrium of the water in regards to calcium carbonate can be determined is by actual trial.

Temperature also has an effect upon the saturation equilibrium of calcium carbonate. The curves shown in Fig. 2 were determined at room temperature, that is, about 20 to 22° C. The other curves are based on actual tests, but not enough were run to state that the curves are absolutely correct. They should be regarded as somewhere near the true lines.

Corrosion prevention by treatment of the water has been demonstrated to be practical and economical. This being true, then it seems that all corrosive waters should be treated.

[1]Baylis, J. R. How to Avoid Loss by Pipe Corrosion. Water Works Engineering, 83:13-14, 31-32, 35-36, Jan. 1, 1930.

[2]Haydock, C. The Cleaning of Cast Iron Water Pipe Lines Jour. Am. Water Works Assoc., 11:533-4, May, 1924.

The Influence of Dissolved Oxygen on Corrosion Losses

Engineers and chemists are constantly studying the theories and mechanics of corrosion because it is only through better understanding of fundamentals that they will be able to diminish losses due to corrosion.

Thirty years ago, R. W. Whitney, now vice-president of the general Electric Company, announced that the corrosion of metals was an electrochemical process and this view is now generally accepted. When a metal is in contact with even slightly acidic solutions, corrosion takes place by the chemical process of the metal replacing the hydrogen in the acid. The acid dissolves the metal and thereby hydrogen is released. The same holds for corrosive waters.

Released hydrogen coats the metal surface with an electrically charged layer that prevents the chemical reaction from continuing at the initial rate. If the hydrogen layer is built up to a sufficient thickness the reaction is practically stopped. However, under natural conditions, the hydrogen combines with the oxygen of the air or that dissolved in the water to form water and solution of the metal goes on. The *amount of oxygen* available to remove the protective hydrogen blanket determines the extent of corrosion.

Impure metals are corroded more quickly as a rule than pure metals. Electrochemists believe that this is due to the impurities taking up the oxygen. Contrary to the popular belief, however, pure metals are subject to corrosion under the action of certain acid solutions. Prof. O. P. Watts of the University of Wisconsin has recently shown that if oxygen is absolutely excluded copper will not corrode in a solution of sulfuric acid, a reaction that is very rapid in the open.

The importance of the dissolved oxygen content of corrosive water is thereby once more emphasized. When this element is present in high concentration a higher pH value must be maintained to prevent corrosion of mains than otherwise; and, particularly of household services or piping subjected to increased temperatures which create accelerated attack.

This suggests that there is some question as to the merits of aeration of waters which are normally aggressive, unless the pH value is raised sufficiently by alkali addition to reduce the hydrogen ion concentration considerably; below that which is commonly considered to represent a neutral water. It has in fact been demonstrated that ofttimes waters high in oxygen content and low in hardness must be raised to pH 9.5 in order to check even the cold water corrosion of mains. In some aerated waters a pH value of 10 to 10.5 is required, which is costly and questionable practice with public supplies.

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CALCIUM CARBONATE encrusted sand taken from filter bed. Threshold Treatment with sodium hexametaphosphate prevents the after-precipitation of calcium carbonate typified by the above rock-like formation.

Section of coil from hot water heater. Threshold Treatment prevents such scale formation from either hard water or softened water.

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THRESHOLD TREATMENT*

A New Method of Stabilizing Water in Softening and Corrosion Control

By CHARLES P. HOOVER

Superintendent, Water Purification Plant, Columbus, Ohio, and

OWEN RICE

Research Engineer, Hall Laboratories, Pittsburgh, Pa.

The prevention of excessive scale formation from hard or from unstabilized lime softened water has been one of the most stubborn problems for water plant operators to solve. The after-precipitation, productive of excess scale, may be very troublesome, for it frequently occurs in the filters, mains, valves, meters, heating coils, hot water storage tanks, pumping equipment and in cooling or circulating systems.

Prevention of scale formation may be accomplished by softening through zeolite, by acid treatment or by lime softening followed by recarbonation. However, if any of these softening processes are carried too far, the treated water becomes corrosive. Controlled protective scale formation, in connection with any of the above-named processes, has been found to be difficult.

For naturally soft corrosive water or zeolite-softened water, it is not unusual to add lime or soda ash to produce protective scale. However, such treatment is not always adequate for too much of the precipitation may take place near the plant where the water was treated and not enough at the far ends of the distribution system to secure the protection sought.

The addition of strong acids to convert carbonates to sulfates or chlorides an excessive quantity of carbon-dioxide which is difficult to remove.

With waters softened with lime, or lime and soda ash, recarbonation of the treated water before filtration is practiced for the purpose of neutralizing any excess lime and for converting the carbonates of calcium and magnesium into soluble bicarbonates and thus prevent undue scale formation. However, if carbon dioxide is added in sufficient quantities to convert all the normal carbonates, a new problem is introduced. It produces the undesirable effect of dissolving colloidal carbonates and thus increases the carbonate hardness.

And so, it is apparent that all previous attempts at controlling scale formation and after-precipitation, in one way or another, have not been altogether successful.

"Threshold Treatment" with Hexametaphosphate

"Threshold Treatment," it is felt, offers a new method of approach. This treatment, developed by Hall Laboratories[1] consists in adding a very small quantity of sodium hexa-metaphosphate $(Na\ PO_3)_6$ to the water. It has been proven that when 2 ppm. (even less in some cases) of sodium hexametaphosphate is added to hard water, or partially softened water such treatment prevents all further precipitation of calcium carbonate. This fact is effectively illustrated in Figure I. Threshold treatment of cooling water, boiler feed water, and in many similar applications where precipitation of calcium carbonate from the water is a problem" offered much to operators of years.[2] These applications were called to the attention of the senior author, and it was readily apparent that the so-called "threshold treatment" offered much to operators of municipal water plants, as a means of eliminating many of the difficulties with calcium carbonate depositions encountered in treatment plants, water supply systems, and consumers' piping systems.

Extensive physiological research on the properties of hexametaphosphate had previously been undertaken at a prominent midwestern university, and when the results of this work demonstrating the absence of any toxic effect, even in relatively concentrated solutions, were presented to the Ohio State Board of Health, permission was readily obtained for trial application in public water supplies in Ohio.

Ohio Plant Tests

The Delaware, Ohio, municipal water plant, which is under the supervision of the senior author, was chosen for the first application of threshold treatment to a municipal lime-soda softening plant. This plant pumps an average of 700,000 gallons per day and has been softening the supply since 1915. By the addition of lime and soda ash, the hardness of the water is reduced from an average of approximately 300 ppm. to 100 ppm. Recarbonation has been practiced since 1923, but in order to avoid dissolving too much colloidal carbonate, recarbonation is not carried to the point where after-precipitation of calcium carbonate is prevented. As can be seen by an examination of the data given in Table I, the average drop in alkalinity through the filters was approximately 30 ppm. From these figures it can be seen that the filters were playing a very important part in the softening process. During the first twenty-four days of May, the alkalinity of the settled water at Delaware averaged 64 ppm., while that of the filtered averaged 31 ppm., showing an average precipitation of calcium carbonate on the filters of 33 ppm. A feed of 2 ppm. of sodium hexametaphosphate was started on the twenty-fifth of May. There was practically no precipitation of calcium carbonate on the filters following this addition. The results are shown in Table No. 1 and Figure II. The results of threshold treatment during June, July and August are also shown in Table 1. During the latter month, the feed was reduced to 1 ppm. and then to ½ ppm. It is evident that the after precipitation of calcium carbonate was entirely prevented even at these lower feeds.

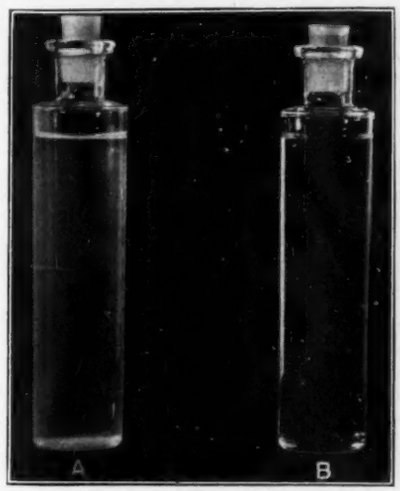


Fig. I—Effect of Threshold Treatment

Both bottles filled with water containing 250 ppm. of calcium-bicarbonate. To bottle "B" was added 2 ppm. of hexametaphosphate—(trade name "Calgon")—before adding 300 ppm. of soda as to each. Results—calcium carbonate clouds appeared in "A" within 5 minutes; in the "Calgon" treated bottle "B" no precipitation is visible 24 hours later.

See Table I for long period results. The effects of "Threshold Treatment" with 2 ppm. of "Calgon" as a precipitation preventive are strikingly evident.

Results Were Striking

While this demonstrated strikingly the tremendous effectiveness of sodium hexametaphosphate in preventing the precipitation of calcium carbonate, it had the disadvantage of preventing the additional softening secured on and within the filter beds. Consequently, where it is desired to obtain the softening action of the filters, the sodium hexametaphosphate should be added following filtration. It will then stabilize the filtered water and will, we believe, prevent or materially modify precipitation

*From Water Works and Sewerage, January, 1939.

throughout the distribution system. Laboratory tests indicate that no precipitation occurs even upon heating fairly hard water to which 2 ppm. of hexametaphosphate has been added. (See Figure III.)

The remarkable results obtained at Delaware in preventing after-precipitation on the sand filters suggest the possibility of adding sodium hexametaphosphate to lime softened unfiltered or high pH softened filtered water before softening through zeolite in order to prevent incrustation of the zeolite mineral.

The entire lime-soda softened water supply at Mt. Sterling, Ohio, is now being treated with hexametaphosphate, and it is proposed to apply it to the entire supply of the City of Columbus, Ohio, after January 1, 1939.

TABLE I.

Effect of Threshold Treatment on After-Precipitation at Water Softening Plant, Delaware, Ohio.
Average Results in P.P.M.*

	Alkalinity			Hardness	Pptd.
Period	Settled	Filtered	City Tap	Filtered	on Sand
1937	69	39	..	108	30
1938—January	76	51	..	118	25
1938—February	70	34	..	95	36
1938—March	68	35	..	94	33
1938—April	66	38	..	99	28
1938—May**	67	38	..	99	28
1938—June	67	66	60	106	1
1938—July	69	69	66	104	0
1938—August	72	73	71	103	—1

*Data obtained from the Ohio State Board of Health.

**Threshold treatment with 2 ppm. was commenced at noon, May. 25.

Threshold Treatment of Hard Waters

It has been difficult or even impossible from a practical standpoint to prevent the sealing up of hot water heaters when water high in hardness and bicarbonate alkalinity is used, except by softening the supply. In Figure III, however, the effect of 2 ppm. of sodium hexametaphosphate in preventing the precipitation of calcium carbonate when water high in bicarbonate hardness is heated is shown. These curves show very conclusively that threshold treatment will prevent after precipitation at high temperature even when the carbonate hardness is extremely high, and likewise indicate that excessive scaling of hot water heaters can be prevented.

Threshold Treatment in Corrosion Control

The application of sodium hexametaphosphate to the problems occurring when lime or other alkalines are added for corrosion control is readily apparent from the above, and was mentioned by R. C. Bardwell in his discusion of this subject, given before the Virginia Section of the American Water Works Association, as recounted in the October issue of "Water Works and Sewerage." Mr. Bardwell reported that a small amount of sodium hexametaphosphate had been found helpful in hot water systems in retarding the rapid deposition rate of calcium carbonate under such circumstances. Since the addition of smaller amounts of sodium hexametaphosphate than are required for complete prevention of precipitation results in a slowing up of the deposition of calcium carbonate, it is also conceivable that partial threshold treatment will provide a means for extending a more uniform and more nearly ideal coating of calcium carbonate throughout the distribution system than is generally attainable.

Conclusion

The plant scale experience at Delaware and Mt. Sterling, Ohio, and a variety of laboratory experiences show that the addition of a small amount of sodium hexametaphosphate will stabilize high carbonate hardness waters. This is valuable, for when excess lime treatment is not needed to reduce magnesium it bids fair to make recarbonation of lime softened water unnecessary, and it may even eliminate softening of hard waters which are softened primarily to prevent incrustations.

The fact that the addition of these small amounts of sodium hexametaphosphate continues to stabilize the water at temperatures approaching the boiling point makes threshold treatment especially valuable in all these applications because trouble with scale in hot water heaters is often encountered even following partial softening or the addition of lime or soda ash for corrosion control.

It seems evident from these data, and experience obtained during the past two years in many similar applications in industrial plants, that wherever problems involving the precipitation of calcium carbonate are encountered in public water supplies, threshold treatment should be considered.

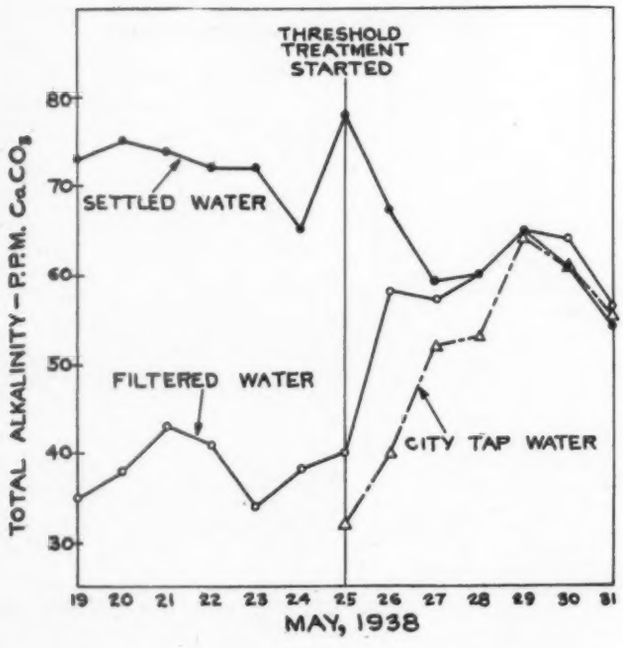


Fig. II.—The Effect of Threshold Treatment at the Delaware, Ohio, Softening Plant.

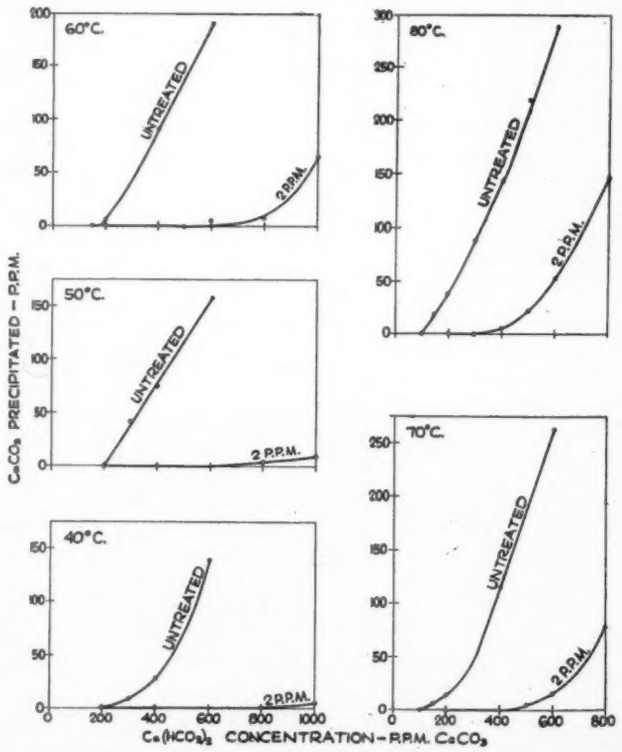


Fig. III—Samples of water of Various Degrees of Hardness Before and After Heating to Various Temperatures Indicated for One Hour.

CHECKING TUBERCULATION BY CHLORAMINE TREATMENT*

By J. WALTER ACKERMAN

General Superintendent, Consolidated Water Co., Utica, N. Y.

The results from the ammonia-chlorine treatment in suppressing tuberculation of the 12-mile cast-iron supply main at Utica, N. Y., constitute a new chapter in corrosion control and depreciating capacity values of water mains.

When Mr. Ackerman first reported his observations informally before the American Water Works Association in 1934, he considered the findings both interesting and indicative, rather than conclusive. Amongst his audience were many skeptics. A year later sufficient supporting data had been accumulated by him to warrant a further informal report before the same association. Now, still a year later, the results are more than ever convincing. It was with this in mind that WATER WORKS AND SEWERAGE asked Mr. Ackerman to present to its reader his data-graphs and the accompanying report of the continuing effectiveness of the treatment which maintains sterile conditions throughout the 12-mile main.—Editor.

The Consolidated Water Co. of Utica, N. Y., constructed in 1906 a single 24-inch cast iron water main for transmission purposes to bring water from the West Canada Creek at Hinckley, N. Y., to Marcy Summit, a distance of 12.1 miles, for the purpose of supplying the city of Utica with water from this source in addition to that already supplied from the southern group of reservoirs. This supplied sufficient water for use in the city until 1922, when the use had increased and delivery of this line had diminished to a point where it was only delivering about 8.5 M.G.D.

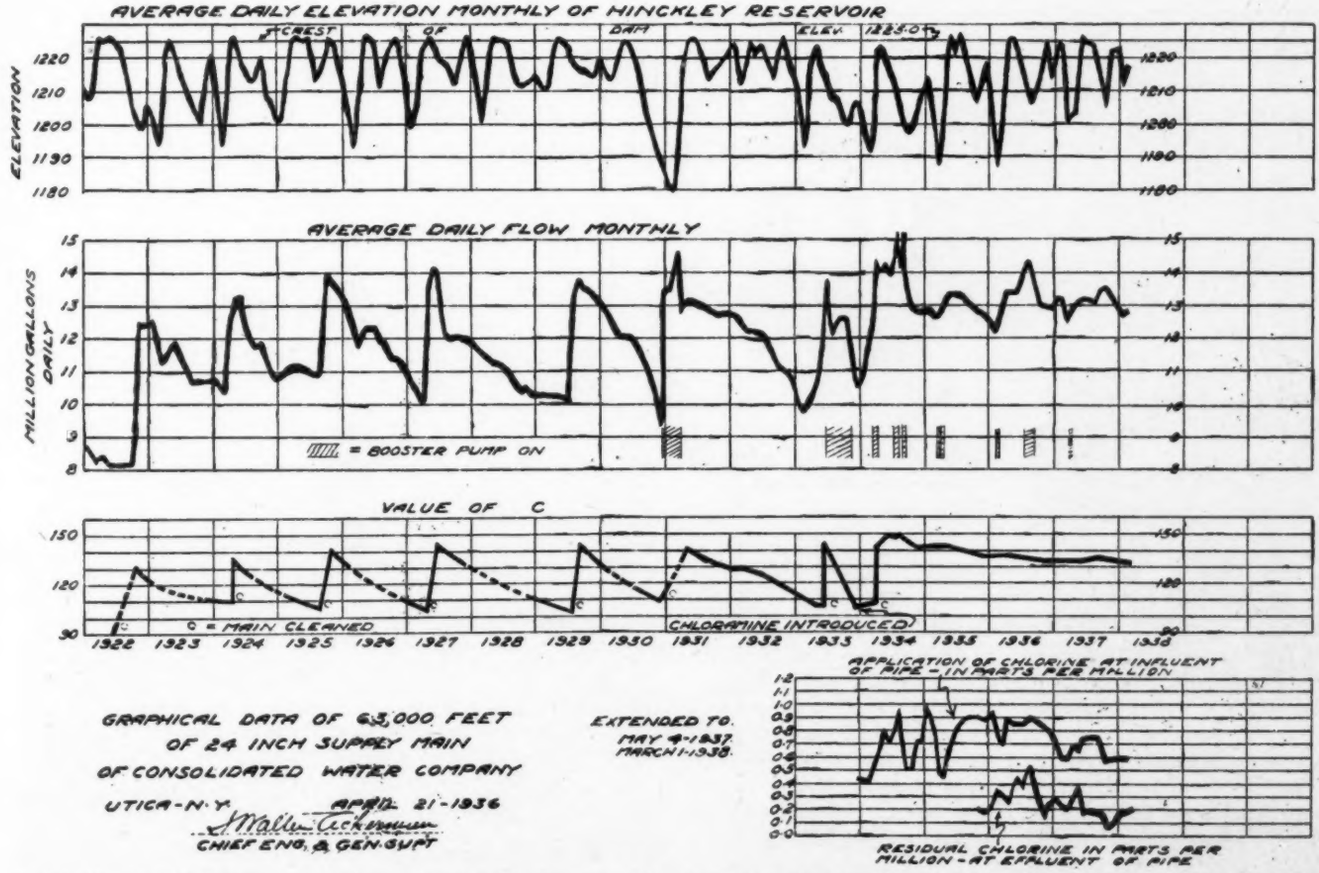
Records in the office indicate that in 1917 this line was examined by Metcalf & Eddy, Engineers, and the value of "C" in the Hazen-Williams formula was found to be 109. On July 5, 1921, "C" had dropped to 95, and in November of the same year it had dropped further to 93.5. It later became necessary to clean this line and the National Water Main Cleaning Company was engaged for this purpose and cleaned it on October 5, 1922.

Table A shows the number of times the main has been cleaned since that date and the various "C" values before and after cleaning.

TABLE A

Date Cleaned	Months Since Previous Cleaning	Reservoir Elevation	—Delivery— Before	After	"C" Before	"C" After
		1199.9	Oct. '22	Oct. '22	June '22	Oct. 8, '22
Oct. 5, 1922		1199.9	8.5	12.3	90	131
		1192.3	Mar. '24	May '22		
Apr. 1, 1924	18	1226.1	10.3	13.2	109	136
		1211.8	Aug. '25	Oct. '25		
Aug. 27, 1925	17	1220.4	10.5	13.9	106	142
		1222.7	Apr. '27	June '27		
May 4, 1927	20	1223.1	10.1	14.2	103	144
		1223.7	July '29	Sept. '29		
Aug. 6, 1929	27	1215.6	10.0	13.8	102	142
		1193.3	Nov. '30	Mar. '31	Nov. '30	Sept. '31
Jan. 3, 1931	17	1249.7	10.2	14.6	109	133
		1223.6	May '33	July '33	Apr. '33	July '33
June 16, 1933	29	1273.8	10.3	14.0	106	136
		1276.4	Apr. 2, '34	Apr. 12, '34		
Apr. 8, 1934	10	1226.1	11.9	13.7	111	144

*From WATER WORKS AND SEWERAGE, May, 1936.



Graph Showing Effectiveness of Ammonia-Chlorine Treatment in Sustaining the carrying Capacity of a Cleaned CI. Main 12.1 Miles in Length. Compare the Friction Coefficient Curve for 1930 and 1934 with That for 1934-1938.

Until December, 1933, this 24-inch line had carried nothing but untreated water, chlorination being carried out at the local distributing reservoirs. In December, 1933, chlorine-ammonia treatment of the water was started at Hinckley, and the "C" value at the time the treatment began was 105. In April, 1934, just prior to the last cleaning, a measurement of "C" showed a value of 111, an apparent improvement of about 6 p.c. in carrying capacity after the four months of treatment by chloramines, without cleaning.

The last cleaning of this line was done as noted on April 8, 1934, and the "C" value was raised from 111 to 144. No mechanical cleaning has been done since that date, but the line has been continuously treated with chloramines to the present time.

The graph accompanying this article shows the variations in the level of the water in the Hinckley Reservoir, which varies the head on this pipe line and consequently varies the flow due to this change in head. It shows the monthly average flow in each month from 1922 to date, also the chlorine application and the resultant "C" value before and since the application of the ammonia-chlorine treatment. The results seemingly speak for themselves.

Method of Checking "C" Value

Just a word as to the method of checking this "C" value. Careful and rechecked determinations of reference level points at each end of the 12.1 miles of pipe have been made. Consequently, physical observations of the water level in the standpipe at one end of the line and the water level at Hinckley Dam at the other end give the actual slope. The amount of flow is determined by a venturi meter, but at no time has the value of the amount of flow been accepted except after being checked by manometer or pitot tube, and, in fact, a number of these determinations are made either by the manometer on the venturi tube or the pitot tube near this same place. Therefore there are some slight variations in the determining of the "C" value of the period from April, 1934, to the present time. While there appears to be somewhat of a downward trend, it is so small as to be almost negligible, as, of course, the different methods of computing the flow vary about 2 to 3 per cent, according to the method used for this determination, which is as close as can be expected for equipment of this nature.

The Marcy standpipe, which is at the lower end of the 12.1 miles of 24-inch pipe in question, is 2.3 miles from Marcy Reservoir, where the actual chlorine residual is taken, as the Marcy standpipe is in a more or less inaccessible location a part of the year. The residual obtained and shown on the chart is less, therefore, than the actual residual at the end of the 12.1 miles of 24-inch pipe, as the chlorine demand in the 2.3 miles to Marcy Reservoir is considerable in this uncleaned and badly tuberculated section of pipe, which we believe is gradually being cleaned by the action of the chloramines.

Addenda—1937-1938

The above article was prepared in April, 1936. From Mr. Ackerman comes the following advice and a new graph, which carries forward the flow and friction data into 1938, although the graph carries the original date—April 21, 1936. The author explains that the data are checked by frequent readings taken from a checking manometer on the venturi tube, and the use of a Cole rod and Lanham rod. These check readings have shown a difference of but 1 to 3 points in obtaining "C" values of 134 to 142 in the Utica situation.

Mr. Ackerman states: "It will be noted that there seems to be a slight diminution of the "C" value during the past year, but hardly enough to make very much difference in our flow. As a matter of fact we are actually getting more water down now than heretofore, which, I think, is due to the fact that all of these figures constitute the result between the Hinckley Dam and our Marcy standpipe only."

"Below the Marcy standpipe to our reservoirs are two lines of pipe, one 24-inch and one a 16-inch. We know that the 16-inch is very badly tuberculated. About three years ago a test was made on it and the 'C' value was down to about 60. But, since we had at least a theoretical capacity greater than the line above, we did not clean these two lines. We do find now that the water does not stand as high in our standpipe with the same dam elevation at Hinckley as heretofore, which rather indicates that the chloramines have been gradually cleaning the 16 and 24 inch lines below the Marcy standpipe."

"These are just some added points to give you a better understanding of the problem."

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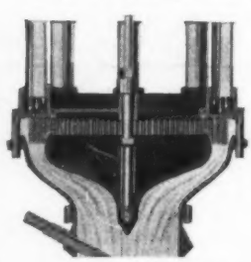

Cross section of Aer-O-Mix aspirator tube head and throat.

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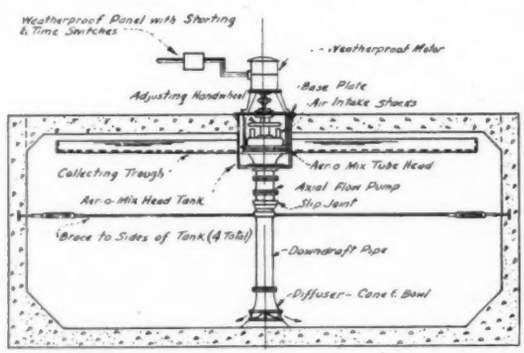

Section Through Typical Sewage Aeration Tank Showing Aer-O-Mix Downdraft Aerator.

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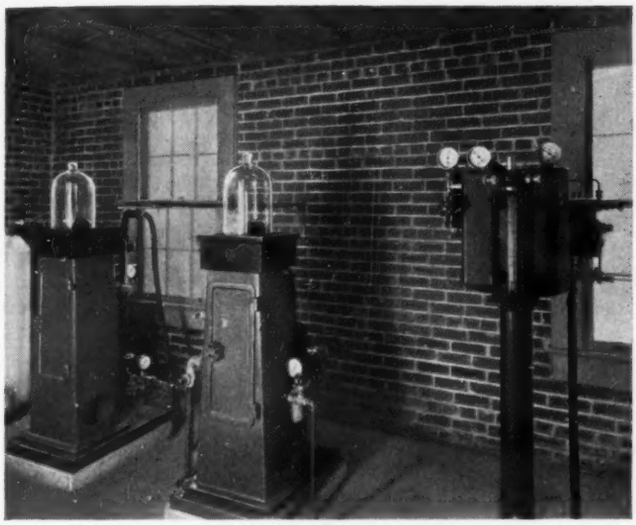

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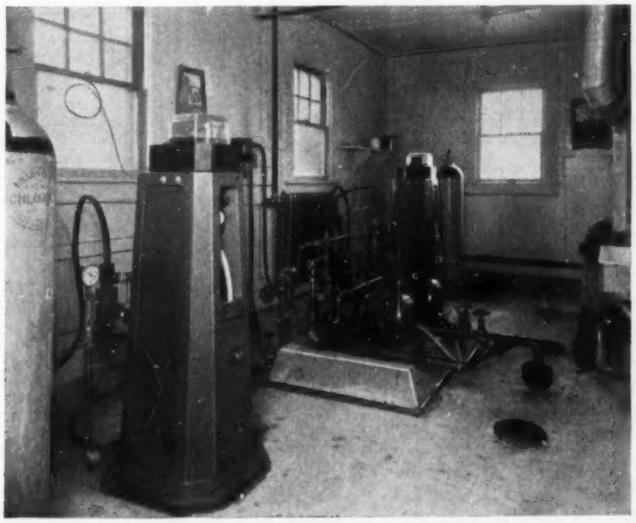

Visible Vacuum Control in low capacity equipments —Duplicate "Equiscale" Chlorinators at New London, Conn.

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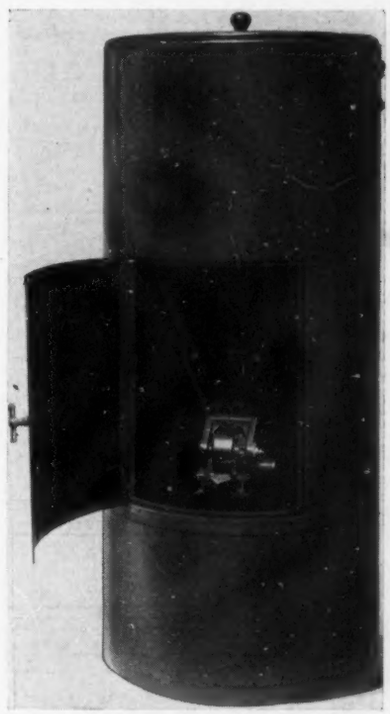

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Current literature on the many phases of chlorination, ammoniation and dry chemical feed is available on request.

LIMESTONE CONTACT BEDS FOR CORROSION CONTROL

Results From Operations of Full-Scale Plant

By I. M. GLACE

Consulting and Supervising Engineer,
Harrisburg, Pa.

In a previous article, which appeared in the January, 1937, issue of WATER WORKS AND SEWERAGE* was described the experimental plant of the Dillsburg Water Co. (Dillsburg, Pa.), and summarized the data which led to the installation of a full-scale plant for the correction of corrosion, using for treatment of the water limestone contact beds. The full-scale plant has been in continuous operation since May, 1937.

The Dillsburg Water Company takes water from a dozen springs located in the sandstone hills to the west of Dillsburg, and serves that borough and adjacent territory. The average daily consumption is estimated at about 40,000 gallons. The water is used without treatment—except as here described—and is collected and distributed by gravity. Originally the distributing and storage reservoir floated on the gravity supply line to the distributing system. Now, under the new method of operation, all of the water must enter the reservoir after passing through contact beds, consisting of crushed limestone rock.

The Unit and Results

The limestone contact bed consists of a concrete basin with inside dimensions, 55 by 5 ft. in plan, and 4 ft. deep (see sketch). It has inlet and outlet chambers and a flowing through compartment, divided into three sections by concrete over and under baffles to induce up and down flow through the crushed limestone. Blowoff lines are also provided for draining and cleaning. A weir at the outlet end is provided for the measurement of the treated water. It is also possible to bypass the entire treatment works and storage reservoir through the gravity main to the system. The tank was waterproofed with "Bitumastic" enamel supplied and placed by the Wailes-Dove Hermiston Co.

The flowing through compartments of the contact bed are filled with crushed limestone, screened to ¾ to 1½ inch size. This material, taken from the stock pile of a local quarry, was originally prepared as aggregate for road work.

The data secured on the operation of the full-scale plant confirm the data secured from the experimental installation described in the earlier article.* The findings also confirm those Cox[1] and Ryon[2], who appear to be the only other persons in this country to have published information on this form of corrosion control. The pH, alkalinity, and hardness of the treated water seem to have increased to about the anticipated extent, with corresponding decreases in the carbon dioxide content. Curves, in which the pH is plotted against contact time, follow approximately the same line, and show a rapid pH increase during first hour of contact, followed by a flattening of the curve on longer retention. However, there is a constant gain add within the time limits recorded up to 3½ hours of contact at least.

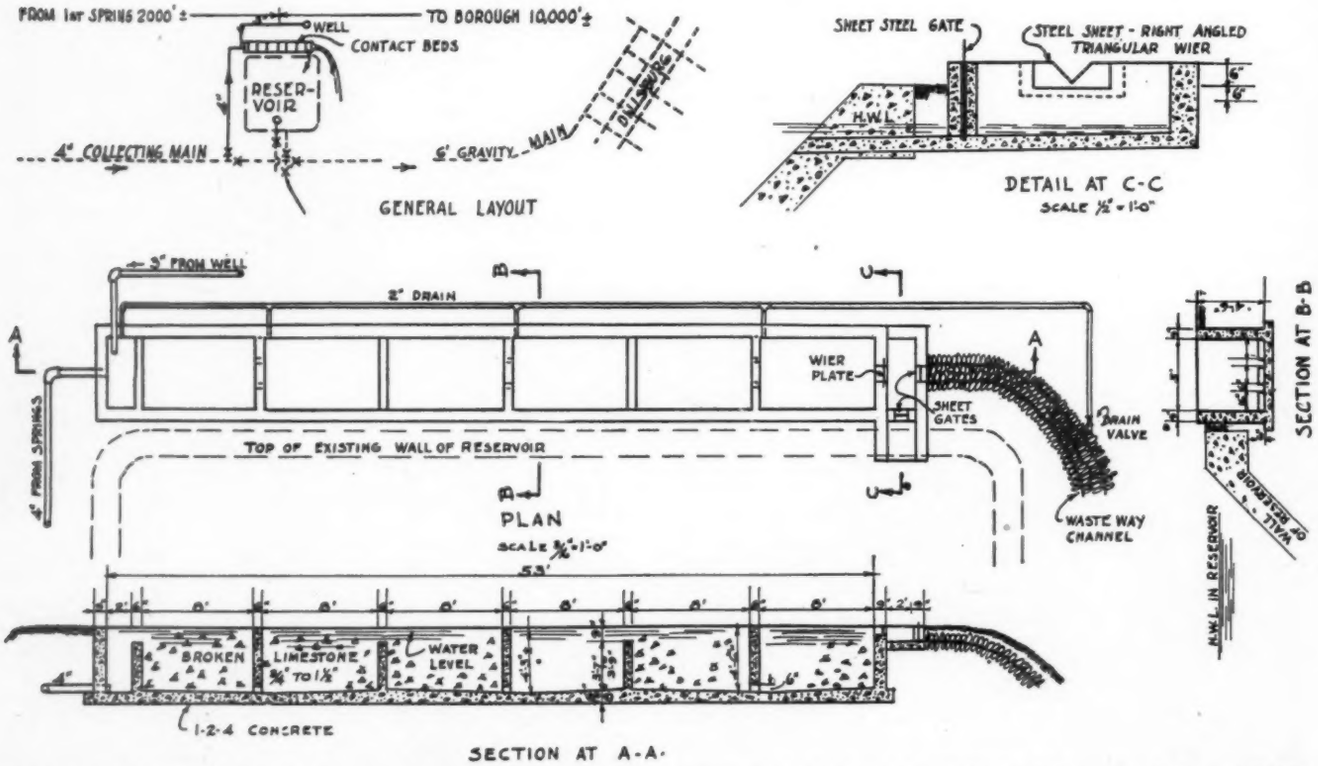
Average figures on raw and treated water are:

		Treated Water†
pH	5.4	7.3
Alkalinity	12 p.p.m.	44 p.p.m.
Hardness	8 p.p.m.	40 p.p.m.
Carbon dioxide	20 p.p.m.	5 p.p.m.

†From contact period of approximately 2½ hours.

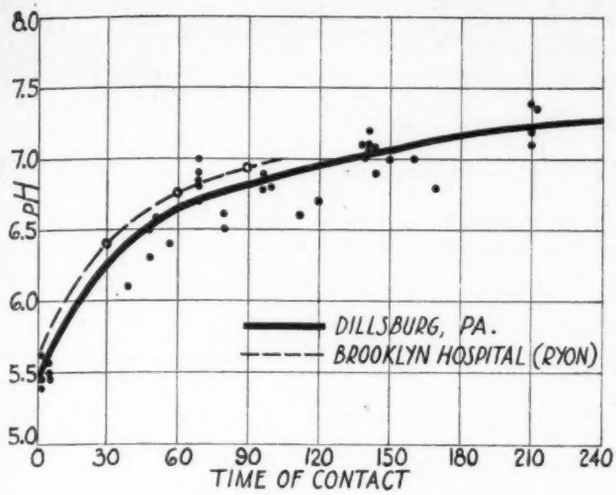
The actual contact period at Dillsburg on full scale has been quite constant over most of the past season, since just enough water is run through the plant to maintain the distributing reser-

*Also reproduced in the Reference and Data Issue of 1938—page 426.



Design of Dillsburg's Hardening Plant, Consisting of Limestone Contact Beds. Designed for 50,000 *G.P.D. at Total Cost of* $1,000.

[Plant scale design based on results from experimental unit consisting of 50 gal. barrel filled with crushed limestone. Tests involved up-flow displacement at metered rates, to determine economical relationship of contact period, loss of head, and grading of limestone—see previous article*]



Graph Picturing Relationship of Contact Period to pH Increase.

voir at or near its maximum level. The calculated period of contact has been close to three hours, based on the assumption that the voids in the stone amount to 50% of the bed volume.

Routine checks in plant operation have been confined mostly to colorimetric pH determinations, rather than by CO_2 tests and other analyses. This has been the case because of the ease and simplicity of the pH test; although it is believed, as judged by more complete data, that this determination alone provides sufficient information to determine efficiencies on a practical operating scale. A series of such tests, typical of many others, is tabulated at this point and will later be discussed.

pH VALUES

(Full-Scale Plant—2½ Hr. Contact)

Inlet	First Baffle	Second Baffle	Plant Outlet	Reservoir Overflow	Taps
5.4	6.8	7.1	7.2	7.5	7.6

Effectiveness and Costs

From the consumers' standpoint, as well as that of the water company, the treatment has been a success. Iron and other metallic tastes have disappeared at the taps, and complaints of stained laundry, formerly frequent, are no longer received. Even water stored in flasks in refrigerators has failed to show the characteristic murkiness and stains common to water carrying iron in solution. The water company has noted, also, a marked reduction in the number of service meters which must be cleaned and replaced. The maximum hardness at the taps in Dillsburg during the past season has been about three grains (50 p.p.m.), which would be considered to be a reasonably soft water by the average water user.

Maintenance costs up to this time have been negligible and apparently will continue to be so for an indefinite time. Only in the down-flow side of the first compartment has there been any measurable reduction in the level of the stone in the bed, or in the size of the stone. Due to the dissolving action of the water, the size of the stone particles in this portion of the bed is likewise noticeably less. Based on admittedly approximate computations and reduced volume of limestone (not all of which is available as calcium carbonate), the rate of solution seems to be about 200 pounds for each million gallons of water treated.

In an attempt to show the efficiency of the treatment, sections of service pipes have been suspended in the water at the inlet and outlet ends of the contact bed, and at two intermediate points. Heavily insulated wire has been used for the hangers, to eliminate possibilities of galvanic action between the metals. These sections of pipe consist of galvanized iron, wrought iron, brass, and copper. Results will be reported later, after more time has elapsed, but the effect of treatment is clear.

An unexpected result of the treatment at Dillsburg has been the markedly improved appearance of the water in the distributing reservoir. This water formerly was considered to be quite clear and had no apparent turbidity. Now, however, it has an extreme clarity and sparkle and a particularly inviting appearance. The reasons for this improvement are not entirely clear. It is possible that the contact beds, filled as they are with coarse material, have served to remove certain colloidal materials from the water.

The total cost of the completed project, including piping changes, was about $1,000 for the plant capable of treating 50,000 gals. per day and upward. The 40 tons of stone used (included in the $1,000), were bought at $1 65 a ton, delivered at the plant. The cost of treatment has been estimated at 15 cents per million gallons as the cost of limestone dissolved.

Discussion

The author desires to emphasize that the economical maximum quantity of water to be treated by contact beds would seem to be in the neighborhood of 500,000 gallons a day, although of course many variables must be considered before a proper determination could be made. Some of these variables would include the character of the water (and more particularly its CO_2 content and carbonate hardness), the physical characteristics of the supply and the accessibility of the proper place for treatment, the head available for aeration, maintenance costs, and similar factors which enter into any well-considered engineering project. The process certainly would seem to be applicable for the treatment of water of institutions, estates, and individual homes in rural areas.

This method of control is not new. Cox, in his article in 1933[1], mentions three foreign installations, particularly one at Frankfurt, Germany, where a plant has been in operation since 1908, treating from 8 to 11 million gallons a day with crushed marble. Ryon, in his article of 1935[2], describes the plant installed at the Creedmor Division of the Brooklyn State Hospital, treating better than a half million gallons a day.

The data so far collected warrants acceptance of the process amongst other methods for the control of corrosion, when such corrosion is due to an excess of carbon dioxide or deficiency in hardness. With normal temperatures, low alkalinities, and high CO_2, a large part of the effect is found to occur in the first half hour, after which, as the alkalinity and hardness increase, the reactions become very much slower—see curves.

One of the interesting points noted in the Dillsburg results is the persistent increase in the pH of the treated water in the storage reservoir after the treated water is discharged from the contact bed. The increase in the reservoir may be due to a further loss of CO_2 in the basin, although the author is disinclined to accept such a theory, which would hardly apply to the action in the piping system. It seems more probable that reaction continues after contact of the water with the stone has been completed, with a further reduction in the number of hydrogen ions, and an increase in the pH scale. This phase has attracted attention only recently, with the accumulation of operating data, and needs further investigation.

Continued maintenance of pH value throughout the distribution system is of particular interest to the author, since it seems to be at variance with results noted elsewhere. In a number of cases where treatment with lime is practiced there is a measurable drop (sometimes very pronounced) in the pH of the water between the point at which the water enters the distribution system and where the water is taken from taps.

References

1. Cox, C. R. The Removal of Aggressive Carbon Dioxide by Contact Beds of Limestone or Marble. (J., A. W. W. A.—November, 1933.)

2. Ryon, Henry. Corrosion Control with a Marble Filter. (W. W. & S., October, 1935)

3. Glace, I. M. Limestone Contact Beds for Corrosion Control. (W. W. & S., January, 1937, and April, 1938, Reference & Data Issue.)

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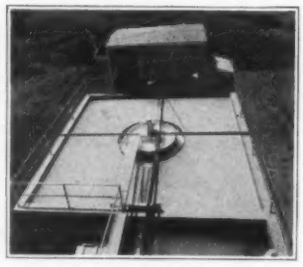

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Infilco Indicating and Recording, Rate of Flow, Loss of Head and Liquid Level Gauges and Illuminated Indicators provide visual indication and permanent records of plant operation.

Infilco Meters accurately measure the flow of a liquid through an Infilco Venturi Tube, and indicate, record and totalize such flow.

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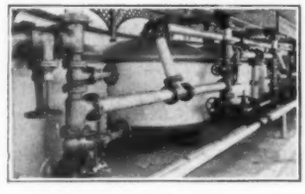
There is Infilco equipment available to satisfy every filtration plant requirement. In addition to those items mentioned elsewhere on this page, there are Filter Operating and Control Tables, Filter Underdrain Systems, Mixing Basin Equipment, Pipe Gallery Specialties, Sampling and Observation Tables, etc. —Every type of equipment required in a filter plant.



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Infilco equipment for the chemical, biological and mechanical treatment of sewage and industrial wastes includes: Activators, Chemical Feeders, Clarifiers, Digestors, Flow Measuring Equipment, Griductors, Hydraulic Controls, Lime Slakers, Mixers and Coagulators, Proportioners, Rotary Distributors and Dosing Siphons, Samplers, Venturi Tubes and Meters.

CONTINUOUS STABILITY AND CORROSIVITY INDICATOR

Provides the Marble Test and Langelier Corrosivity Index Continuously

By LINN H. ENSLOW, Editor
Water Works and Sewerage

The so-called Marble-test has been employed for some years as a laboratory procedure in determining the degree of aggressivity, or the scale forming qualities of waters. In short, the marble test has been employed to reveal the stability of waters. It has served as a valuable guide in properly proportioning chemicals in water treatment—whether it be softening or, the reverse, hardening with lime or alkalinization by other means to reduce corrosivity.

Now, in more recent times, considerable has been heard about Langelier's Saturation Index as a measuring stick for evaluating the corrosivity of waters.

The Marble-test has its shortcomings, requires some exactness in manipulation and there are influencing factors to be considered. In addition it requires time of chemists or operators in properly preparing for and conducting the test. Those who have employed the test will appreciate the significance of these statements.

The Langelier Index, as a measure of corrosivity, has been tested and demonstrated to be scientifically correct. It, however, has the drawback of requiring the services of an analyst, application of corrections, and computations. The fact that changes in raw water quality necessitates new analytical determinations to arrive at the Saturation Index detracts from its value as a practical guide or control method in day to day anti-corrosion treatment.

With the thought in mind of simplifying the marble-test, making it dependable and non-time consuming, and at one operation revealing the Langelier Index by making but two simple pH determinations, the device illustrated in the accompanying sketch suggested itself as a continuous stability indicator.

It is immediately apparent that with this contact device, in continuous service, the chemist or operator will find a prepared sample of marble-treated water awaiting his arrival at the plant, day or night. And, without doing anything about it, another will be ready at any time to reveal the effectiveness of altered chemical dosages.

Parts Involved

The "Continuous Stability Indicator," as it has been christened, is simple to construct. It consists of the following parts:

A—Glass or metal tube filled with powder.

B—Twin tube filled with marble or limestone chips, or coarse silica sand. (This tube functions as a trap for swept over chalk powder. Also colloidized chalk, if any, will plate out on the grains.)

C—Plugs of compacted glass-wool, or other suitable supporting and straining material.

D—Stop-cocks or pinch-cocks, for regulating flow rate, and in disconnecting apparatus, etc.

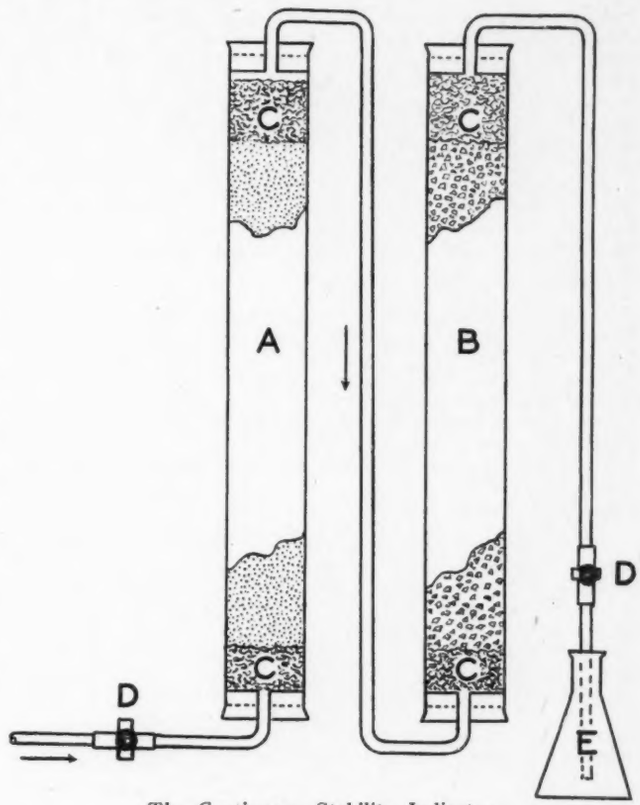
E—Flask or bottle, slowly but continuously overflowing with carbonate saturated water. (From this reservoir portions are drawn for comparison with influent water, in respect to pH value and total or alkalinity.)

Test Procedure

Two samples of water are taken. Namely, some of that from the pipe line feeding the device and some of the effluent water collected in the flask or bottle.

A simple titration of these "before and after" samples for total alkalinity will reveal whether the treated water from the plant (or any unit of it) is a marble dissolving (corrosive) water, or is a carbonate depositing (scale forming) water, and to what extent.

If it be desired to determine the Langelier Saturation Index for record, or use as a control check, a simple pH determination



The Continuous Stability Indicator.

on the "before and after" samples yields the Index Number by nothing more complicated than subtraction of the two pH values. For example: If the pH reading on the influent water is 8.0 and the effluent is 8.4 then the Langelier Index Number is $8.0 - 8.4 = -0.4$. All that this means is that the calcium carbonate hunger of the water had not been completely satisfied in treatment by the amount of carbonate to raise the pH value 0.4. Had the pH value not changed the Index would have been 0, indicating a perfect balance—a saturated water. Had the pH value been 8.8 at the influent and 8.4 at the effluent the Index would be $8.8 - 8.4 = +0.4$, indicating a sludge or scale depositing water—commonly referred to as unstable water.

Question of Contact

An important question in connection with operating the Stability Indicator is how much of a contract period is to be required?

The answer is that this varies with various waters and the period must be determined. Ordinarily two hours will prove an ample contact with finely pulverized chalk, and even one-half this period may prove ample in practical operating control. However, there is not any reason why the rate of feed should be more than a dribble. There is no such thing as too long a contact period in respect to complete stabilization of water with calcium carbonate.

CORROSION CONTROL BY DEAERATION

By SHEPPARD T. POWELL[1] and H. E. BACON[2]
Baltimore, Maryland

All branches of engineering in which the handling of water is involved have found the corrosion of ferrous materials to be a major problem. Preventive methods have been developed as more detailed knowledge of the corrosion process has been gained. At the present time the mechanism of corrosion under various conditions has been the subject of considerable experimental and theoretical study and is fairly well understood. It is well established that the attack of water upon iron results in a concentration of hydrogen ions at the surface of the metal, which stops the corrosion process under the conditions usually encountered in ordinary water for domestic or industrial use. Dissolved oxygen in the water reacts with this protective hydrogen, which is thus removed, and in consequence permits the attack on the metal to continue. Speller lists the oxygen concentration as first in importance among the factors in corrosion by water in the neutral zone.

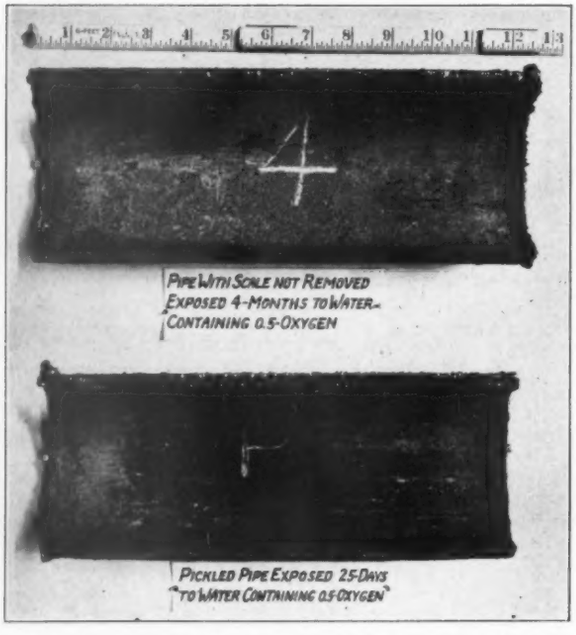
Protective Coatings

Many methods of corrosion control seek to prevent the water from coming in contact with the metal, by interposing protective layers of various kinds. These may be deposited chemically, as in the case of films which confer passivity on the metal, or scales formed from minerals in the water. Protective coatings and linings are also applied in the form of various paints and cements. Efforts to prevent the corrosion of water mains are generally effected in this way, and when carried out properly such treatment is successful.

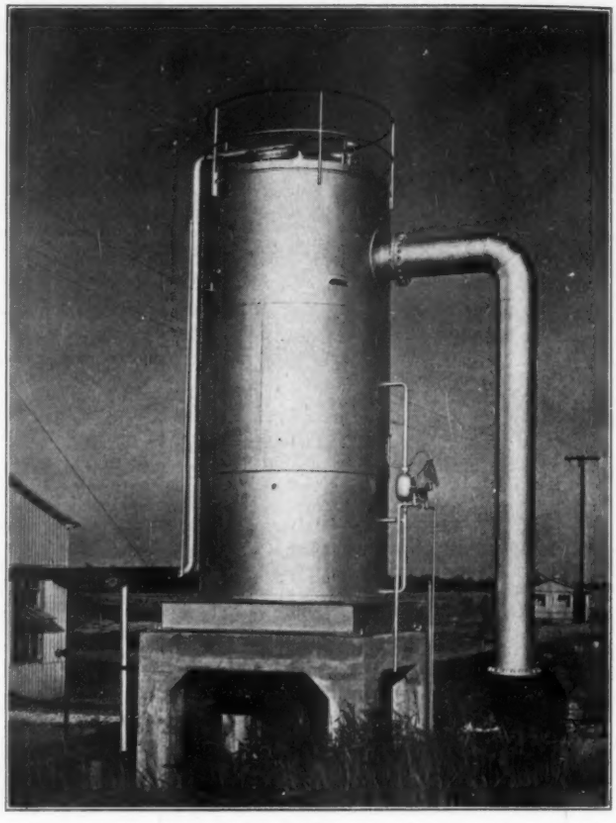
Oxygen Removal

Since dissolved oxygen is generally necessary for the continuous attack of water upon ferrous materials, considerable attention has been given to removal of this gas from water. It is a well-established fact that corrosion of pipes carrying hot or cold water can be enormously curtailed merely by removal of dissolved oxygen from the water. Such treatment is regarded as imperative for boiler feedwater and is accomplished by elevating the temperature, to reduce the solubility of oxygen, and venting the gas which is evolved. Chemical reducing agents are frequently used to complete the deaeration of the water. Hot water heaters have been used to a limited extent for partial deaeration of hot water used in large buildings, and cold water has been deactivated by apparatus which provided for removal of oxygen by contact with scrap iron. However, removal of dissolved oxygen has not been widely practiced except for the deaeration of boiler feedwater.

*From WATER WORKS AND SEWERAGE, April, 1937.
[1]Consulting Chemical Engineer and [2]Associate.



A Dual Demonstration in Corrosion Control. (Below) The Non-Corrosiveness of Deoxygenated Water on Bare Smooth Walled Steel Pipe. (Above) The Effect of Mill-Scale in Increasing Corrosion, Even in the Practical Absence of Dissolved Oxygen and pH Values Approaching 8.2



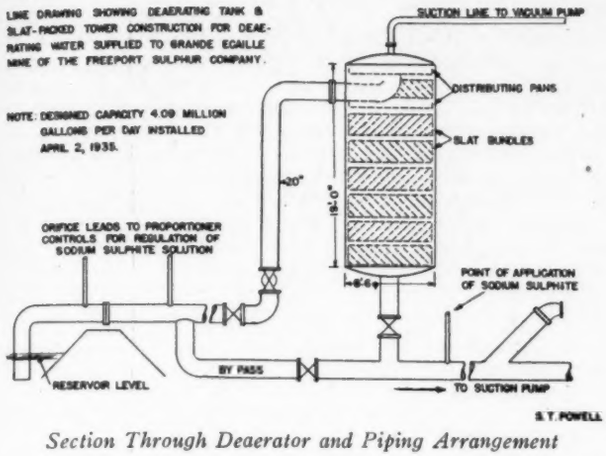
The Completed Deaerator. Capacity 4 *M.G.D. Vacuum* 28 *to* 28.5 *Inches. (For Details and Dimensions, See Sketch)*

Freeport Sulphur Co.'s Problem

The Freeport Sulphur Comany, operating mines in Louisiana and Texas, has encountered the problem of corrosion in connection with its water supply system, and the corrective methods adopted have attracted considerable interest. This company has developed the sulphur resources in the Mississippi delta below New Orleans, with a mine located at Grande Ecaille, Louisiana. Since the sulphur mining process requires large volumes of hot water and it is also necessary to generate considerable steam, an adequate water supply is essential to this industry. This was obtained by establishing a reservoir and pumping station at Port Sulphur, located on the Mississippi river nine miles from the mine. The reservoir water is pumped from here to the property through an uncoated steel pipe. This line is welded and is carried on piles and passes under water only at bayou crossings.

Provision was made for supplying 4,090,000 gallons per day, which was required for operation at the desired rate. However, in four months the carrying capacity of the line decreased nearly 25 per cent due to corrosion of the pipes, which likewise seriously threatened the destruction of the pipe. An examination of the pipe revealed excessive tuberculation, which accounted for the marked rise in the coefficient of friction and consequent depreciated carrying capacity of the line, and increased pumping costs.

Consideration was given to lime treatment to inhibit aggressivity of the water, involving the possibility of producing on the pipe walls a thin protective coating of calcium carbonate. The river water, however, was not susceptible to the precipitation of calcium carbonate by this treatment, because the pH of the settled river water was approximately 8.0, no bicarbonate alkalinity being present most of the time. Sodium silicate was applied in the hope that a silicate scale could be deposited, but evidence


LINE DRAWING SHOWING DEAERATING TANK & SLAT-PACKED TOWER CONSTRUCTION FOR DEAERATING WATER SUPPLIED TO GRANDE ECAILLE MINE OF THE FREEPORT SULPHUR COMPANY.
NOTE: DESIGNED CAPACITY 4.09 MILLION GALLONS PER DAY INSTALLED APRIL 2, 1935.
SUCTION LINE TO VACUUM PUMP
DISTRIBUTING PANS
SLAT BUNDLES
20'
18'-0"
8'-6"
ORIFICE LEADS TO PROPORTIONER CONTROLS FOR REGULATION OF SODIUM SULPHITE SOLUTION
POINT OF APPLICATION OF SODIUM SULPHITE
RESERVOIR LEVEL
BY PASS
TO SUCTION PUMP
S.T. POWELL

Section Through Deaerator and Piping Arrangement

indicated that corrosion continued, or was retarded so little that the treatment was not justified. Further, there was definite evidence that silicate scale was developing in the boilers, and, fearful of consequences, the immediate termination of the silica treatment was determined on.

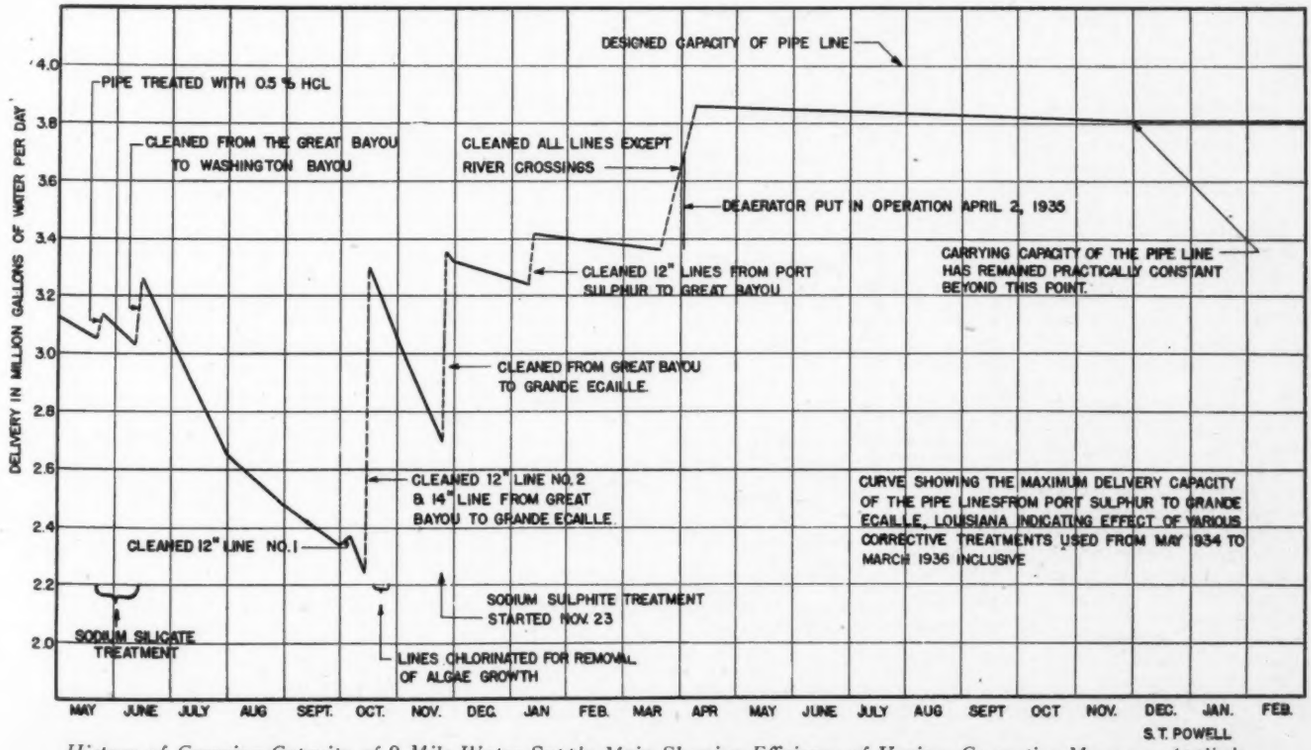
Oxygen Removal Turned to

These experiences led finally to consideration of deaeration of the supply as that treatment which would insure a most overall satisfactory solution of the problem. The oxygen present in the water varied between 6 and 10 parts per million, and exceeded the saturation value at times because of the presence of prolific growths of micro-organisms. Deaeration with sodium sulphite was undertaken experimentally, and almost immediately a reduction was noted in the rate at which the capactiy of the line was decreasing. The expense of chemical deaeration would have been prohibitive, however; and, having served to demonstrate the efficiency of deoxygenation, it was not considered as a permanent treatment. In view of the proven benefits of dissolved oxygen removal, steps were taken to design equipment for mechanically deaerating the water by passing it through an evacuated chamber.

The only previous large-scale application of the deaeration process had been at Coolgardie, Australia, where 6,000,000 gallons of water per day are deaerated to protect a 350-mile pipe line. Inquiries directed to the officials in charge of this latter installation brought the information that excellent results were being obtained, which confirmed statements appearing somewhat earlier in the technical literature. As a result of the investigation and the favorable record of the Australian plant, a cold water deaerator was designed. This consisted of a tower, into the top of which water was to be introduced in the form of a relatively fine spray, dropping into a collecting chamber at the bottom of the unit, from which it could be pumped into the pipe line. The apparatus was to be maintained under a specified vacuum and the gases, flashed from the water, removed by the vacuum pump. An adequate seal was designed so that the desired vacuum could be maintained. Calculations were made to determine the operating characteristics of various designs and the required vacuum pump capacities and cost factors involved in installation and operation.

On the basis of this information a small pilot plant, having a capacity of 100 gallons per minute, was built. This equipment differed from the earlier designed unit in that the tower was packed with wooden slats over which the water trickled in thin films from which gases were readily released. Experiments were made to determine the oxygen removal resulting when the water was dropped from various heights and when different degrees of vacuum were maintained. These tests showed that approximately 95 per cent oxygen removal from the water was effected [0.33 p.p.m residual oxygen] when the deaerating chamber was under a vacuum of 28.5 inches. The curve of oxygen removal becomes almost horizontal at this vacuum and further reduction in pressure requires rapidly increasing pump capacity because of the much larger volume of the rarified gases under the lower pressure. It was determined that the remaining 5 per cent of dissolved oxygen could, therefore, be removed most practicably and economically by means of the deoxygenating sodium sulphite than by extending the mechanical process. The type of deaerating unit constructed as the pilot plant was a much less expensive form of construction than the Australian apparatus, and, since excellent results were obtained, it was used as the pattern in designing the full-scale plant.

Water deaerated by the pilot plant was passed through a 4-inch discharge line for a period of three months. At the end of this period the line was inspected and sections of the pipe were cut longitudinally. No tuberculation was found, and by comparison with control specimens carrying undeaerated water it was obvious that corrosion was almost entirely inhibited. In each case portions of pipe from which the mill-scale has been removed by pickling were inserted in the line. This was done in order to evaluate the harmful effect of mill-scale on past operation. The pipe which contained mill-scale was much more seriously attacked by water with normal oxygen content than was the pickled (cleaned) speci-


DESIGNED CAPACITY OF PIPE LINE
PIPE TREATED WITH 0.5 % HCL
CLEANED FROM THE GREAT BAYOU TO WASHINGTON BAYOU
CLEANED ALL LINES EXCEPT RIVER CROSSINGS
DEAERATOR PUT IN OPERATION APRIL 2, 1935
CLEANED 12" LINES FROM PORT SULPHUR TO GREAT BAYOU
CARRYING CAPACITY OF THE PIPE LINE HAS REMAINED PRACTICALLY CONSTANT BEYOND THIS POINT.
CLEANED FROM GREAT BAYOU TO GRANDE ECAILLE.
CLEANED 12" LINE NO. 2 & 14" LINE FROM GREAT BAYOU TO GRANDE ECAILLE
CLEANED 12" LINE NO. 1
CURVE SHOWING THE MAXIMUM DELIVERY CAPACITY OF THE PIPE LINESFROM PORT SULPHUR TO GRANDE ECAILLE, LOUISIANA INDICATING EFFECT OF VARIOUS CORRECTIVE TREATMENTS USED FROM MAY 1934 TO MARCH 1936 INCLUSIVE
SODIUM SULPHITE TREATMENT STARTED NOV. 23
SODIUM SILICATE TREATMENT
LINES CHLORINATED FOR REMOVAL OF ALGAE GROWTH
DELIVERY IN MILLION GALLONS OF WATER PER DAY
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
MAY JUNE JULY AUG SEPT. OCT. NOV. DEC. JAN FEB. MAR APR MAY JUNE JULY AUG SEPT OCT NOV. DEC. JAN. FEB.
S.T. POWELL

History of Carrying Capacity of 9-Mile Water Supply Main Showing Efficiency of Various Corrective Measures Applied

men. With deaerated water, however, the corrosion was very slight, even in the presence of mill-scale, although it was apparent that pickling had been of some benefit in this case also.

Plant Scale Installation

Observations on the pilot plant and calculations for a full-scale unit were so encouraging that a large deaerator was constructed, capable of treating the entire supply of 4,000,000 gallons per day, for which the pipe line was designed. The deaerating apparatus is illustrated in the accompanying sketch and photograph. It will be noted that the vacuum maintained is sufficient to draw the water from the reservoir into the deaerator. The water is distributed over the slat bundles by two perforated pans and is discharged to the suction of the pump feeding the pipe line. Sodium sulphite is applied at a point between the deaerator and the pumps. This chemical is fed by means of a Cochrane proportioner. The water is pumped through the 9-mile line by three 10x8-inch HYC two-stage Allis-Chalmers centrifugal pumps. A Worthington 18x7-inch dry vacuum pump, with an overall efficiency of 39 per cent, is used for maintaining a vacuum of 28 to 28.5 inches in the deaerating tower.

Results of Treatments

The result of this treatment and the entire history of the pipe line are strikingly illustrated in the chart picturing carrying capacities. It will be noted that since the deaerator was put into operation in April, 1935, decrease in carrying capacity has occurred at a very slow rate, and at the present time this curve has become practically horizontal. The pipe line has been inspected at several points and it is apparent that tuberculation has been almost entirely stopped. It is therefore believed that deaeration of the cold water is an entirely satisfactory solution to the very serious problem with which this company was faced. Moreover, this installation has afforded a practical demonstration of the feasibility of mechanically deaerating even large quantities of cold water where the protection of pipes of ferrous material is desired.

Acknowledgment.—We wish to express our appreciation of the assistance and co-operation of W. T. Lundy, vice-president and general manager, and Homer S. Burns, vice-president, of the Freeport Sulphur Company, which have made the project a success and this article possible.

SOLUTION FEED CONTROL*

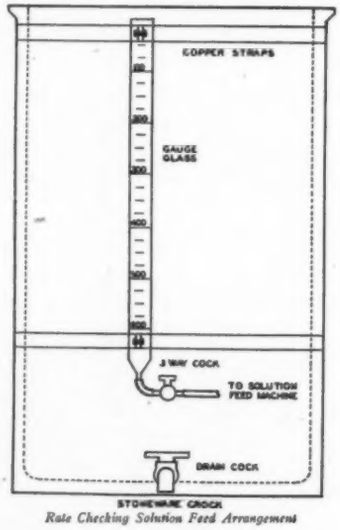
By T. M. RIDDICK

Consulting Chemist, New York City

Within the past few years there has been a rapid increase in the use of solution feed equipment for pressure filters, and small water supplies with pumping rates of less than about 700 GPM. This trend now fills the long-felt need for apparatus of a capacity below that of standard dry feed machines or vacuum-type chlorinators. These feeders are of diaphragm or piston type and discharge roughly a maximum of 250 ml. per minute for single units, with duplex rating of approximately twice this figure. Experience with both plunger and diaphragm pumps, operating under a negative head, emphasizes the possibility of flow stoppage due to clogging of suction or discharge lines, loss of prime through air leakage, air binding, etc. If the machine is fed by a suction hose extending over the rim of the solution crock it is most inconvenient and difficult to judge at what rate the solution is being added, and whether the discharge is constant.

A new type of solution feed arrangement is shown in the accompanying drawing. It has been used with excellent success by the writer.

The crock illustrated is a fifty-five gallon stoneware pot of substantial construction. The draincock can be furnished as standard equipment and provides an easy way of drawing off sludge which will in time accumulate from commercial chemicals. Six inches above the center line of the draincock is placed a three-eighth inch three-way hard rubber cock and T. (See sketch.) This location prevents clogging of the feed line by sludge or chemicals which have not completely dissolved. (It is better to have this cock installed at the factory, since the hole may be drilled more readily at the shop than in the field.)



Rate Checking Solution Feed Arrangement

Rate Checking Solution Feed Arrangement

The gauge glass is made by drawing down one end of heavy-walled Pyrex tubing of 38 mm. diameter. The tube, as pictured, is calibrated at 25 ml. and number marked at 100 ml. intervals. However, it may be graduated at intervals of 10 ml. with no overcrowding of division lines. The gauge glass enables the operator to observe the height of solution in the crock without close inspection, and also affords a means for measuring the amount of solution used daily since the tube calibration may be interpreted in terms of gallons of crock capacity, or, pounds of chlorine, alum, ferric-chloride, etc.

In order to ascertain the specific rate of feed, it is only necessary to turn the three-way cock 180 degrees. This causes the solution to be drawn from the gauge glass instead of from the crock, and by noting the time (in seconds) required for a drawdown of say 100 ml., or, by observing the drawdown in ml. for a period of one minute, the rate of discharge of the feed machine can be accurately established.

It also serves as a very ready method for determining whether or not the machine is feeding at all. For instance, clogging of the feed line often occurs when using chemicals shipped in burlap bags, due to small threads which pass into the crock when bags are emptied.

The gauge glass is held in place by two copper or monel straps, which secure it to the solution pot.

It is advisable to attach a high speed mixer to the crock to assist the operator to quickly and easily prepare solutions. When hypochlorites or ferric salts are used the shaft and propeller of the mixer should be coated with rubber or heavy bituminous enamel.

The cost of the equipment is negligible when considering the operating facilities afforded.

*From WATER WORKS AND SEWERAGE—March, 1938.

CONTROL OF ALGAE

By FRANK E. HALE, Ph.D., Dept. of Water Supply, New York City

Note also "COPPER SULPHATE in WATER PURIFICATION," by Paul Weir in Magazine Section of this Issue.

Knowledge of microscopic organisms and their control is one of the more important aspects of water supply practices. Chief amongst agents utilized in algae control is copper sulphate, its application to reservoirs being known as "coppering."

The simplest manner of application is to drag burlap bags, containing about 50 pounds each, through the water by means of rowboats, taking a zigzag course so as to triangulate the surface of the water. Wind, waves, diffusion and gravity admix the streaks of treated water with the remainder. Crude as this method is, it has been found very effective. But it is essential that the chemical be well distributed.

[Recently there has been effectively used by the Los Angeles Water Department a mechanical broadcasting device on the rear of a launch. It distributes pulverized copper-sulphate over the water surface in a manner equivalent to that used in broadcasting fine grass seed. This method reaches shallow shore-line areas most effectively. See Jour. Review, Feby., 1936.]

The reservoir should be partitioned into arms by land sights and the capacity, in million gallons for total depth, calculated for each area so that dosage may be correctly apportioned. In the case of organisms predominating in the upper water, dosage may be calculated on the upper 20-30 feet only. About 3,000 pounds a day may be distributed by a single launch in favorable weather.

Calculation of the volume of a body of water is not difficult. Two formulas should be kept in mind:

One cubic foot contains 7½ gallons.

One gallon of water weighs 8⅓ pounds.

Estimate the area in square feet. Estimate the average depth in feet by soundings. Multiply the two for cubic feet. Multiply cubic feet by 7½ to find gallons and express in million gallons. In the table of treatment which follows one column reads directly in pounds of copper sulphate per million gallons of water to apply for each genus of organisms.

To calculate amount of copper sulphate needed from "Parts per million" column multiply million gallons by 8⅓ to obtain million pounds of water. Multiply this figure by the amount shown in the column headed "Parts per million."

Two formulas are helpful to bear in mind:

1 pound per million gallons = 0.12 part per million.

1.0 part per million = 8⅓ pounds per million gallons.

Copper sulphate may be fed to an aqueduct by continuous dry-feed to destroy organisms feeding from one reservoir to another. The effective dosage is identical with that employed in open reservoirs by the launch method.

Another frequently employed method of continuous feed of copper sulphate is by solution feed. On a small scale a wooden bucket may be suspended in the flowing water so arranged that its depth of submersion may be varied. A small hole in the bottom of the bucket admits the water. The bucket is filled with copper sulphate and a definite amount added once or twice a day and the depth of submersion regulated so as to dissolve the determined quantity each day.

Three to four hundred pounds per day may be fed by the barrel arrangement shown. By this equipment the chemical is applied as a saturated solution and the application is very uniform. The barrel is kept constantly full of water from a supply controlled by a float valve with glass ball. From the bottom of the barrel, through rubber, glass and copper tubing, the solution is discharged to the water at the most turbulent point. The flow is regulated by a pinch-cock. The barrel sets on a scale so that the weight of chemical delivered may be checked. The water consumed varies with temperature and other conditions from about 1¼ to 2½ gallons per pound of chemical dissolved.

Copper sulphate is very soluble in water. The following table may be useful in feed regulations at various water temperatures:

SOLUBILITY OF COPPER SULPHATE

Temperature: °C.	°F.	Pounds of Copper Sulphate Crystals ($CuSO_4 . 5H_2O$) Per 100 lbs. solution	Per 100 gallons water
0	32	19.5	126.0
10	50	23.1	226.8
20	68	26.9	269.4
25	77	28.9	296.1
30	86	31.3	326.1
40	104	35.2	371.1
50	122	39.1	433.7
60	140	44.5	521.3
80	176	55.5	717.2

Spraying with strong copper sulphate solution is advantageous in some instances, *e.g.*, in shallow bays and on floating masses of certain organisms. For this purpose a spray pump or equipment such as is used with insecticides for trees is available. [An alternate procedure is that used by Los Angeles to mechanically broadcast the pulverized sulphate previously mentioned.—Ed.]

Walls of basins have been sprayed for growths such as Spirogyra, using a 5 per cent solution.

Experience differs with waters of different composition, with temperature, and with amount of organisms present as to the right dosage to apply for each organism. About twice as much chemical is required in winter as in summer. It is a waste of chemical to apply an insufficient amount. If a smaller dosage fails, the entire larger dosage must be applied at one time. The water usually clears within three to four days when the correct quantity has been applied. [See Dosage Tables.] Weeds in general are not killed by copper sulphate. Sometimes fish are killed, but rarely in quantity. The following table indicates the susceptibility of fish to the chemical:

LIMITING SAFE DOSAGE OF COPPER SULPHATE FOR FISH

Fish	Parts per million	Pounds per million gallons
Trout	0.14	1.2
Carp	0.33	2.8
Suckers	0.33	2.8
Catfish	0.40	3.5
Pickerel	0.40	3.5
Gold Fish	0.50	4.2
Perch	0.67	5.5
Sunfish	1.35	11.1
Black Bass	2.00	16.6

Chlorine Treatment

Chlorination is the most valuable adjunct to copper sulphate in control of microscopic organisms. In the first place it helps destroy the odors set free by the copper sulphate treatment. In the second place it destroys many *genera*, in several instances the very ones least affected by copper sulphate.

The use of chlorine in increased dosage has slowly been extended not only to destroy organisms but also the distasteful oils. Experience to date indicates that with soft waters the following effects have been noted:

EFFECTIVE CHLORINE DOSAGES

Organisms Units per cc.	Chlorine ppm. Dose	Residual	Effect— Org. destroyed	Taste destroyed
Synura 1—25	0.3	.05-.10	Yes	Yes
Synura 50—100	0.5-0.7	.20	Yes	Yes
Synura 200	0.7-0.9	.30	Yes	Yes
Uroglena 2,000	0.5	.10	Yes	Yes
Uroglena 6,000	0.5	.10	Yes	No
Dinobryon 500	0.5	.10	Yes	Yes
Asterionella 1,350	0.7	.20	Yes (50%)	No
Aphanizomenon 1,500	0.7-0.8	.20-.25	Yes (50%)	No

Prechlorination with high dosage, 1 ppm. and higher, is employed now quite extensively in conjunction with filtration to destroy or prevent growth of microscopic organisms in sedimentation and reaction basins and lessen their interference with filtration. Longer filter runs are obtained in addition to lightening the bacterial load upon the filters.

Miscellaneous Data. *Cyclotella* has been destroyed by dosage of 1 ppm. *Crenothrix* is another troublesome organism which is readily controlled by chlorine or chloramine in dosage of 0.5 ppm. Chlorine in dosage of 0.33 ppm. has readily controlled or prevented formation of jelly masses or fungus slime in well supplies and in mains and prevented clogging of condensers.

Crustacea, such as *Cyclops* and *Daphnia*, have been controlled on occasions. *Daphnia*, red variety, has been controlled with 1 ppm. chlorine and *Cyclops* with 3 ppm. chlorine.

The following table contains data brought up to date on dosages of copper sulphate and dosages of chlorine required for microscopic organisms, including also odors and tastes produced. It is based on published data and personal experience.

CHEMICALS REQUIRED FOR CONTROL OF DIFFERENT GENERA*

Organisms—Odor:	Copper Sulphate[1] Parts per million	Copper Sulphate[1] Pounds per mil. gals.	Chlorine ppm.
Diatomaceae:			
Asterionella‡	0.12*-0.20*	1.0-1.7	0.5*-1.0*
Aromatic, geranium, fishy			
Cyclotella†‡			1.0
Faintly aromatic			
Diatoma†			
Faintly aromatic			
Fragilaria†	0.25	2.1	
Melosira†‡§	0.20*	1.7	2.0
Meridion			
Aromatic			
Navicula†	0.07	0.6	
Nitzchia§	0.50	4.2	
Synedra†‡	0.36*-0.50*	3.0-4.2	1.0
Earthy			
Stephanodiscus	0.33	2.8	
Tabellaria‡	0.12*-0.50*	1.0-4.2	0.5*-1.0
Aromatic, geranium, fishy			
Chlorophyceae:			
Cladophora†	0.50	4.2	
Closterium	0.17	1.4	
Cœlastrum†	0.05-0.33	0.4-2.8	
Conferva†	0.25	2.1	
Desmidium	2.00	16.6	
Dictyosphærium‡			0.5*-1.0
Grassy, nasturtium, fishy			
Draparnaldia	0.33	2.8	
Eudorina	10.00	83.0	
Faintly fishy			
Entomophora	0.50	4.2	
Gloeocystis			
Offensive			
Hydrodictyon†	0.10	0.08	
Very offensive			
Microspora	0.40	3.3	
Palmella	2.00	16.6	
Pandorina	10.00	83.0	
Faintly fishy			
Protococcus			1.0
Raphidium	1.00	8.3	
Scenedesmus	1.00*	8.3	
Spirogyra†	0.12	1.0	0.7-1.5
Staurastrum	1.50	12.5	
Tetrastrum			1.0
Ulothrix	0.20*	1.7	
Volvox‡	0.25	2.1	0.3*-1.0
Fishy			
Zygnema	0.50	4.2	
Cyanophyceae:			
Anabæna‡	0.12*	1.0	0.5*-1.0
Moldy, grassy, vile			
Aphanizomenon‡	0.12-0.50*	1.0-4.2	0.5*-1.0*
Moldy, grassy, vile			
Clathrocystis	0.12*-0.25*	1.0-2.1	0.5*-1.0
Sweet grassy, vile			
Cœlosphærium‡	0.20*-0.33	1.7-2.8	0.5*-1.0
Sweet grassy			
Cylindrospermum	0.12	1.0	
Grassy			
Microcystis	0.20	1.7	
Oscillaria†	0.20-0.50*	1.7-4.2	1.1
Rivularia			
Moldy, grassy			
Protozoa:			
Bursaria			
Irish moss, salt marsh, fishy			
Ceratium†‡	0.33	2.8	0.3*-1.0
Fishy, vile, (rusty brown color)			
Chlamydomonas	0.50-1.0	4.2-8.3	
Cryptomonas	0.50	4.2	
Candied violets			
Dinobryon‡	0.18*	1.5	0.3*-1.0
Aromatic, violets, fishy			
Endamœba histolytica (cysts)			25.0-100.0
Euglena	0.50	4.2	
Glenodinium	0.50*	4.2	
Fishy			
Mallomonas	0.50	4.2	
Aromatic, violets, fishy			
Peridinium	0.50*-2.00	4.2-16.6	
Fishy, like clam-shells			
Synura‡	0.12*-0.25	1.0-2.1	0.3*-1.0
Cucumber, muskmelon, fishy, bitter taste			
Uroglena‡	0.05*-0.20*	0.4-1.6	0.3*-1.0
Fishy, oily, cod-liver oil taste			
Crustacea:			
Cyclops†‡§			1.0 -3.0
Daphnia†‡§	2.00	16.6	1.0 -3.0
Schizomycetes:			
Beggiatoa†	5.00	41.5	
Very offensive decayed			
Cladothrix	0.20	1.7	
Crenothrix†‡	0.33 -0.5*	2.8-4.2	0.5*
Very offensive decayed, medicinal with chlorine			
Leptothrix†			
Sphaerotilis, natans†	0.40	3.3	
Very offensive decayed			
Spirophyllum†			0.25*
Thiothrix†‡			0.5*-1.0
Fungus:			
Achlya			0.6*
Leptomitus	0.40	3.3	
Saprolegnia†	0.18	1.5	
Miscellaneous:			
Chara†	0.10 -0.50	0.8-4.2	
Nitella flexilis†	0.10 -0.18*	0.8-1.5	
Objectionable			
Potamogeton†	0.30 -0.80	2.5-6.7	
Nais†			1.0*
Blood worm, chironomus†			15.0-50.0
Blood worm, gnats			3.0

The organisms where odors are expressed have been in sufficient quantity at one time or another to cause the characteristic odor.

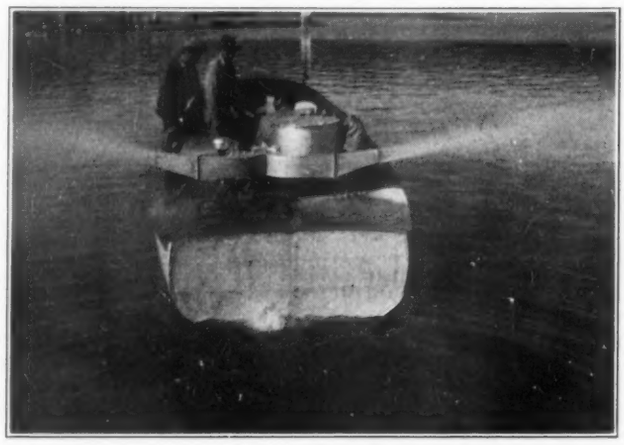
[1]The quality of water (hard or soft) and temperature has a decided influence on the requisite copper dosage. The harder the water, and the colder, the higher the dosage required. To under-treat is a waste of chemical and further—the whole dosage must be applied at one operation.

*Dosage successful in New York City's supplies.

†These organisms have caused trouble other than odor.

‡These organisms have been affected by chlorine producing characteristic odor and in many cases controlled by dosage ranging from 0.3 to 3 ppm., depending largely on amount of organisms.

§Controlled by excess caustic lime, 5 ppm., in the case of diatoms (48 hrs.).



Los Angeles' Improved Dry-Feed Coppering Machines Used in Algae Control, Surface Applications Have Proved More Economical and Effective. All Shallow Areas Are Reached Easily.

COPPER AND HEALTH

The effect of copper on health is a subject of such importance to all users of copper and brass and copper sulphate for algae control, that the conclusions in an article read before The New England Water Works Association* are given below:

1. The copper content of domestic drinking water after passing through copper or brass pipe or tubing, even if a slight amount of copper is taken into solution, is not harmful to health. It may indeed be beneficial.

2. All water supplies intended for domestic use after passing through a proper installation of copper or brass pipe or tubing will contain but a small percentage of the permissible copper content, if any at all.

3. The permissible copper content of domestic water based on a consumption of one gallon of water a day should apparently not be greater than 20 p.p.m.

4. It is unlikely that health will be injured by copper because, where the copper content is above 5 p.p.m., the taste of the water will generally be so disagreeable that it will be virtually impossible to drink it.

5. No anxiety need be felt about a proper installation of copper or brass pipe or tubing, because it has been shown that with acid water having a pH value of about 6.5, the copper content is generally only about 0.5 p.p.m., even after standing in the pipe lines for an appreciable length of time.

6. The treatment of reservoirs with copper sulphate to rid them of undesirable microscopic growths has no injurious effect on health.

*Journal N. E. W. W. A., 44: 4, December, 1930.

TASTE AND ODOR CONTROL PRACTICES

By F. E. STUART, President

Activated Alum Corporation, Baltimore, Md.

Taste and odor control is now second only to the production of a safe water. The cost has been studied carefully and has been weighed against its importance as a routine treatment.

Now that the economics of taste and odor control by applying large dosages of powdered activated carbon have been compared with the economics of closely controlled coagulation, involving carbon adsorption, a new flow scheme is becoming apparent. A combination of these two methods of treatment appears to be the most overall efficient and economical.

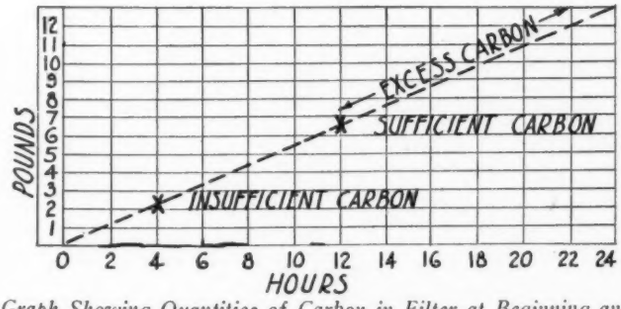
A short review is necessary to bring up to date the work that has been done on carbon by observers in the field. Further, to point out why this new type taste and odor control flow scheme is the most practical.

When alum is added to water and coagulation is produced, a large percentage of taste producing elements in the raw-water is precipitated in the settling basins. This is common practice and the effectiveneness coagulation is taken for granted.

Previous to the introduction of activated carbon, these precipitated impurities underwent decay and generated gases and liquids of decomposition, which contaminated the newly coagulated water passing through the basins. Putrefying and liquefying sludge in the settling basins is a more common cause of tastes and odors than generally realized. A high chlorine demand in the filtered water and of tastes in dead ends are created by the same phenomena. This is not difficult to appreciate when one remembers how badly the basins smelled when they were last cleaned.

Carbon in the Coagulation Stage

At Daytona Beach, Fla., Superintendent Tippins in 1931 found that carbon used in the coagulation process would inhibit bacterial activity in the settled sludge—resulting in odorless sludge and odorless filtered water. These findings were later confirmed by Furman at Toledo, Ohio, and Fitzgerald at Norfolk,



Graph Showing Quantities of Carbon in Filter at Beginning and End of Each Filter Run When Adding Carbon Continuously to the Applied Water. (Based on Dosage of 12 lbs./MG. and Filter Runs Averaging 24 Hrs.)

Va. This effect of carbon on coagulated sludge has become known as "Stabilization of Sludge."

Because of the good results obtained, other observers added carbon to the mixing chamber in dosages sufficient to remove the tastes and odors present,—dosages between 18 and 32 pounds per million being the most common.

Middlestadt in Sacramento, Cal., about this same time made a careful study of the amount of carbon needed to stabilize sludge and found this dosage to be very small—from 2 to 4 pounds per million gallons. In a recent survey 54 per cent of the plants now using carbon for taste and odor control have been adding small dosages of carbon to the mixing chamber to stabilize sludge and condition the filter sand.

Split Dosage

Later work showed a further reduction in the cost of carbon treatment by utilizing a split treatment; adding half of the total carbon dosage to the mixing chamber and half to the water flowing to the filters. More complete taste control has been accomplished thereby.

Comparing the results between large dosages of carbon added continuously to the water flowing to the filters, large dosages added to the mixing chamber and split treatment the last proved to be the most economical. This brought about the latest change in treatment practice—adding the total amount of carbon to each filter after washing (about 4 to 6 pounds per million gallon filter area) and the addition of sufficient carbon to stabilize sludge and condition the filter sand, along with the alum dosage. A convenient method of doing the latter is to utilize the ready prepared activated alum which contains the required quantity of powdered carbon.

The floc produced by activated alum is more easily controlled than ordinary alum, because of the millions of tiny activated carbon particles which assist in the formation of the floc. A stable sludge will result and stable filter sand also, because the carbon particles are distributed throughout the floc. The floc does not break down as easily as ordinary alum floc and it has been found that less residual alumina is present in filtered water when activated alum is used.

Filter Dosing

Individual observers, led by Smith at Richmond, Va., showed reason why carbon should be added in one "Shot" dosage to the filter *after* washing instead of adding carbon continuously to the water flowing to the filter.

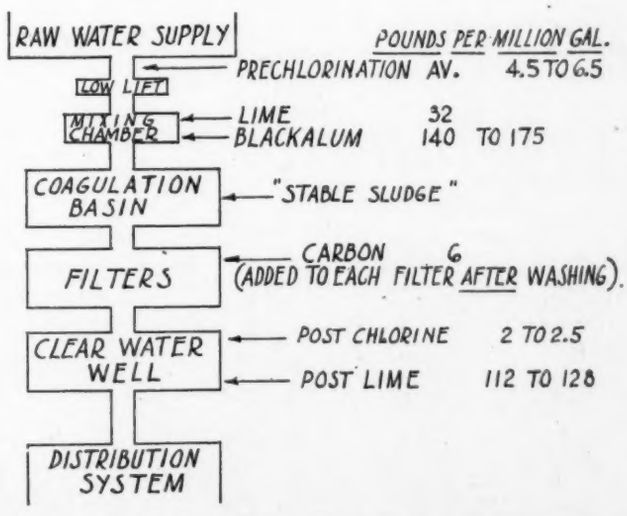
The common basic reasoning for such applications is that with carbon added continuously to the water flowing to the filters (we will say 12 pounds per million gallons), there is more carbon on the filter when it is taken out of service for washing than at any other time. Likewise, there is insufficient carbon on the filter for the first few hours of service, unless higher dosages than actually needed are applied. By estimating the amount of carbon actually needed for each run the dosage if added all at one time, produces a big saving in carbon. Average dosage of 4 to 6 pounds, per million gallons of filter area, seems to meet requirements between filter washings.

The following typical new type flow scheme for taste and odor control is used by Mills of the Southern Pines, N. C., Water Department:

Treatment	Pounds per Million Gals.		
Prechlorination	4.5	—	6.5
Lime, average	32		
Black-Alum (Activated Alum), average	140	—	175
Activated Carbon	6*		
Post Chlorine, average	2	—	2.5
Post Lime, average	112	—	128

*Carbon added to each filter following the wash.

This review points out why taste and odor control can be obtained more economically by means of good coagulation and car-



A Suggested and Tested Flow Scheme—That of Southern Pines, N. C.

bon added to each filter immediately after washing—than high dosages of carbon at any one point in the treatment.

Carbon is now regarded as a routine treatment—to improve coagulation and remove tastes.

Carbon in the pretreatment through activated alum and the addition of 4 to 6 pounds of carbon per million gallon of filter capacity (added all at one time to the filter after washing) is now considered the most efficient and economical method. (See flow scheme).

For serious taste and odor epidemics which are only temporary, large dosages of carbon are necessary and should be applied as a split treatment.

Ammoniation

Suggested by Enslow and probably first introduced by Jordan at Indianapolis, Indiana, later adapted in many plants including Easton, Pa.; Trenton, N. J., and Fort Pierce, Fla., etc., the trend in ammonia application during the past year has been in connection with its use after filtration; it being added after the post-chlorine dosage.

This seems to be the most economical method of application because the dosage of ammonia used is that to combine with only the existing free chlorine.

Users of ammonia continue to favor anhydrous ammonia in cylinders because of ease of application and accuracy of control.

It is well known that ammonia, unless used in the proper concentration in the pretreatment, will in many instances increase algae growths along the sides of the settling basins. This increase in algae growth is controlled, however, if high dosages of ammonia and chlorine are used. These high dosages are uneconomical, and, therefore, prechlorination alone is generally adopted as the most economical practice; adding the ammonia after filtration.

Chlorination

The benefits of such a versatile product as chlorine cannot be outlined in more than a general way. Chlorine in the pretreatment is becoming more generally used, because prechlorination has several advantages in routine plant operation. All plants should have duplicate chlorinators for post-treatment and provisions for prechlorination.

Experiences of the writer have been that high residuals in prechlorination are not advisable at any time. High prechlorination residuals hinder taste and odor control.

High prechlorination residuals are not necessary to improve coagulation or lengthen filter runs. Experiences of Fitzgerald at Norfolk, Va., show that the typical "water flea" can be stunned with prechlorination, without a residual reaching the filters. Prechlorination at the rate of 8 pounds per million gallons was just as effective as 30 pounds. The chlorination did not "kill," but "stunned" them to such an extent that the alum floc would precipitate them and then the filter runs lengthened out.

Many other experiences with chlorine in the pretreatment confirm the writer's opinion that it is a most useful tool to improve general plant operation, but should not be used in concentrations to produce high residuals in applied water. Especially is this true when dealing with algae tastes.

Acknowledgment: This article has been drawn largely from a paper read by the author before the Kentucky-Tennessee Section of A.W.W.A., March, 1936.

Inclined Diagonal Pipe Runs—Calculating Pipe Lengths

By CHARLES FRICK

Darby, Pa.

Water works men may find the following formulas interesting and helpful in figuring lengths of pipe and tie rods on inclined diagonal runs.

The formulas are also useful in finding the approximate angle of fitting, theta (θ), required (when bell and spigot pipe and fittings are used) when the dimensions in three planes have been decided upon.

The evolution of the formulas (see illustration) are also given in case the principle of revolution to a vertical plane may have further advantages in similar problems.

The subtraction of the center to end of spigot and center to back of bell taken from D gives the true length of pipe required.

Sketch Explanatory of Formulas for Lengths of Pipe for Diagonal Runs and Angle of Fittings

A.—When measurements in three planes are known, then

$$D = \sqrt{A^2 + B^2 + C^2} \qquad \text{Formula I}$$

$$L\ (\theta)^{-\tan} = \frac{\sqrt{A^2 + B^2}}{C} \qquad \text{Formula II}$$

Example: Let A = 5′6″, B = 3′0″, C = 14′9″
Find (θ) and length of pipe required on 8″ line.

$$D = \sqrt{(5.5)^2 + (3)^2 + (14.75)^2}$$
$$= \sqrt{30.25 + 9 + 217.56} = 16.025' \text{ say } 16'0''$$

$$L\ (\theta)^{-\tan} = \frac{\sqrt{(5.5)^2 + (3)^2}}{14.75} = \frac{\sqrt{30.25 + 9}}{14.75}$$
$$= \frac{\sqrt{39.25}}{14.75} = \frac{6.265}{14.75} = 0.42474$$

L (θ) = 23° + and a one-sixteenth curve may be used.
Length of pipe = D — (C to E of S. + C to B of B.)
= 16′0″ — (2′1″+) = 13′11″—

B.—When measurements in two planes are known and angle of fitting (θ) decided upon, then

$$D = \sqrt{A^2 + B^2} \times \text{Csc } (\theta) \qquad \text{Formula III}$$

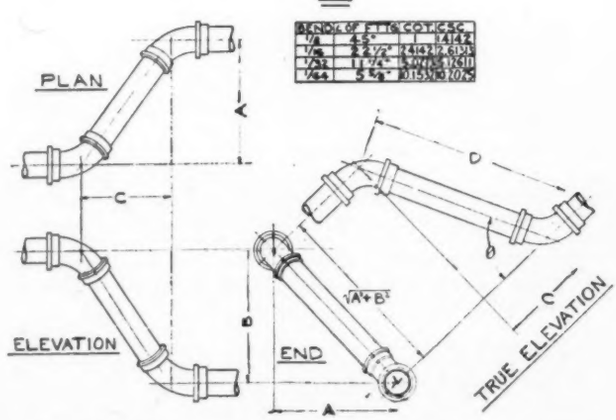
$$C = \sqrt{A^2 + B^2} \times \text{Cot } (\theta) \qquad \text{Formula IV}$$

Example: Let A = 8′0″, B = 9′6″, (θ) = 45°
Find—C and length of pipe required on 12″ line.

$$D = \sqrt{(8)^2 + (9.5)^2} \times \text{Csc } 45°$$
$$= \sqrt{64 + 90.25} \times 1.4142$$
$$= 17.56' = 17'6\tfrac{3}{4}''$$

Length of pipe = D — (C to E of S. + C to B of B.)
= 17′6¾″ — (2′1⅞″) = 15′4⅞″

$$C = \sqrt{(8)^2 + (9.5)^2} \times \text{Cot } 45°$$
$$= \sqrt{64 = 90.25} \times 1$$
$$= 12.42 \times 1 = 12.42' = 12'5''$$



Sketch Explanatory of Formulas for Lengths of Pipe for Diagonal Runs and Angle of Fittings

EVERSON MANUFACTURING COMPANY

Water Purification Systems, Chlorine Sterilizing Apparatus, Swimming Pool Filters, Fittings, Lights and Equipment

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Everson Water Sterilizing Apparatus

Offers a complete line of dependable apparatus for measuring, controlling and introducing chlorine in solutions as used for sterilizing drinking water, swimming pools, sewage, etc. Included in this line are units of the four leading types, each in many capacities, namely: (1) Rota-Meter Chlorine Gas Sterilizers; (2) Pulsating Meter Chlorine Gas Sterilizers; (3) The Safety Electric Sodium Hypochlorate Sterilizers and (4) Chemical Feed Sterilizers.

Everson Rota-Meter Chlorine Gas Apparatus

This equipment is recommended for applications requiring extreme accuracy of control and wide capacity range. Rota-Meter Units have a capacity range of 1 to 10. EVERSON Rota-Relay Units (pat. applied for) permit capacity range as great as 1 to 60. Gas Flow is measured by spinning rota that rises and falls in minutely calibrated, tapered tube, readings fully visible at all times. Cabinet (CRC and DCRC), Panel (PRC) Buffet (BRC) and Standard Models.

Everson "G Line" Chlorine Gas Apparatus

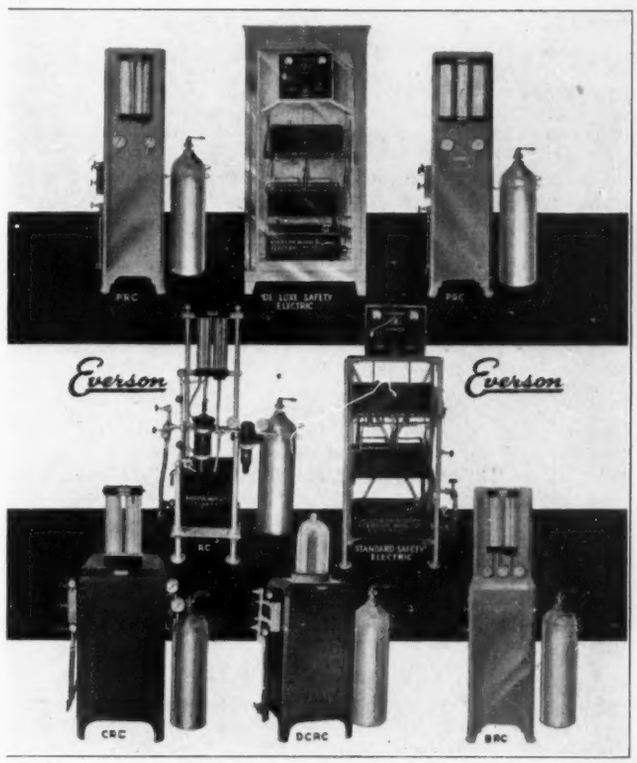
These low priced sterilizers are of the pulsating type widely used on swimming pools and smaller water supply jobs. They are long-lived, thoroughly dependable units for measuring, mixing and feeding chlorine gas from pressure drums into solutions. Standard (G) and Panel types (PGC) available.

Everson Safety Electric Sterilizers

The most advanced type of equipment for indoor swimming pools and applications where long-lived germicidal action is beneficial. These patented units manufacture, electrically under rheostat volume control, Sodium Hypochlorite from ordinary rock salt and water. They obviate the need for special vaults and venting required by most codes where Chlorine Gas is used.

Everson Chemical Feed Sterilizers

Chemical Feed Chlorinators are used primarily where low initial cost is imperative. They provide means for feeding prepared (dry) chemicals in solution for water conditioning and sterilizing.



Everson Water Sterilizing Apparatus

Since 1903 EVERSON has specialized in the development and manufacture of water purifying systems. The modern swimming pool is largely the result of EVERSON development as is much of today's more accurate, dependable and economical sterilizing equipment for water works and sewerage plants.

Everson Re-circulating Filtering Systems

Over 25 years ago EVERSON pioneered the development of Re-circulating Systems for purification of swimming pool water and since that time has been designing and perfecting Filters, Controls, Sterilizers, Coagulators, Water Level Controls, Hair and Lint Catchers and special flow meters, gauges and controls.

Everson Re-circulating Fittings

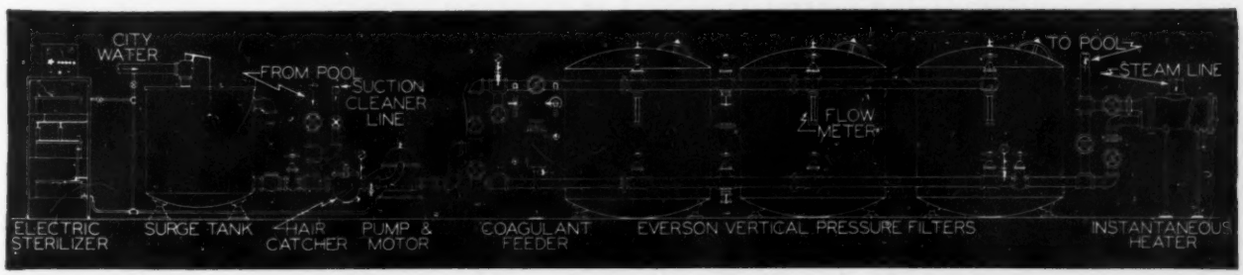
EVERSON Pool Fittings offer unique advantages wherever water is to be re-circulated. Typical of this line is the Adjustable Flow Inlet Fitting that permits easy balancing of the system, simplifies piping and lowers piping costs.

Everson Underwater Lights

Designed for permanent underwater illumination EVERSON Underwater Lights have special lenses. Built-in types for side walls and completely self-contained units (niche-type). Write for catalog.

Everything for Swimming Pools

If it's for the swimming pool EVERSON has it. Not only the water conditioning and sterilizing equipment but pool ladders, diving stands, safety equipment, built-in and portable suction pool cleaners, foot baths and supplies.



Everson Filtering and Sterilizing System for an Indoor Pool

See Our Advertisement on Page 91, This Issue.

LIQUID CHLORINE*

Properties of Chlorine

Chlorine is never found free in nature. Gaseous chlorine is manufactured by the electrolysis of a sodium chloride solution. It is then purified and liquefied by a process of compression and refrigeration. As an article of commerce, chlorine is an amber-colored liquid approximately one and one-half times as heavy as water. It is marketed in steel containers which are under pressure. In Fig. 1 is shown the relation between temperature and vapor pressure.

When the pressure is released, liquid chlorine volatilizes into a greenish-yellow gas which is approximately two and one-half times as heavy as air. Chlorine is non-inflammable, non-explosive, and a non-conductor of electricity. Generally speaking, in the absence of moisture it is not corrosive to common metals. In the presence of moisture gaseous chlorine reacts avidly with a majority of known substances.

Following is listed the more important chemical and physical properties of chlorine at standard conditions (32° F. and 1 atm. pressure) unless otherwise noted:

	Atomic	Molecular
Chemical Symbol for Chlorine....	Cl	Cl_2
Chemical Weight Relationship...	35.457	70.914
	Gaseous Chlorine	Liquid Chlorine
Specific Gravity	2.49* (air = 1)	1.47† (water = 1)
Weight per Cubic Foot...	0.201 lb.	91.70 lb.
Volume per Pound	4.98 cu. ft.	0.011 cu. ft.
Specific Heat		0.2230†
Liquefying Point		— 28.5° F.†
Freezing Point		—151.6° F.‡
Latent Heat of Evaporation		121.0 B.t.u.†
Critical Temperature		294.8° F.†
Pressure at Critical Temperature		1233 lb. per sq. in.
1 Volume Liquid		456 vol. gas

*Leduc †Kneitsch ‡Lange

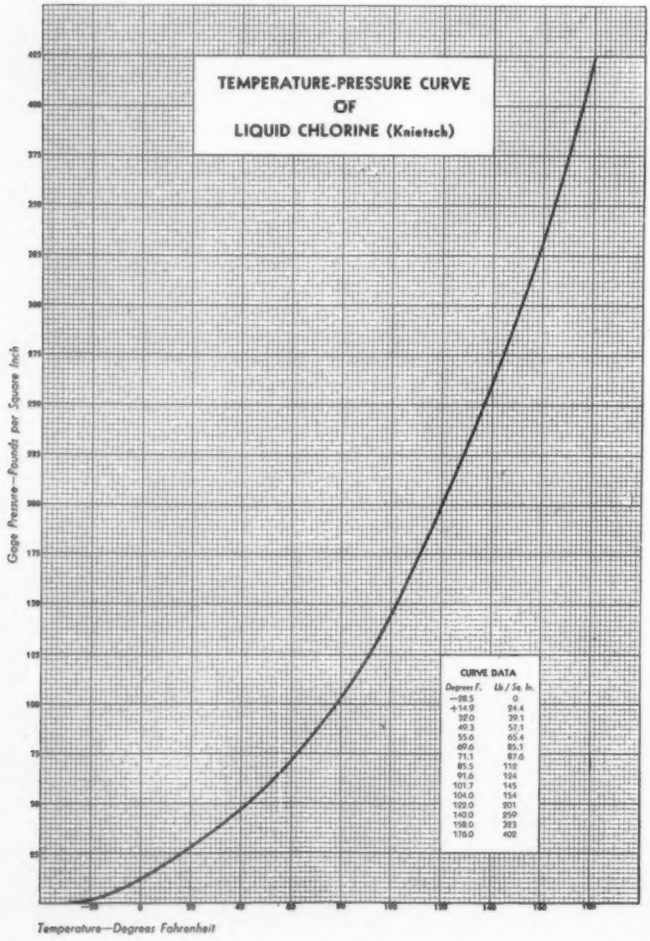


Fig. 1—Relation between Temperature and Vapor Pressure

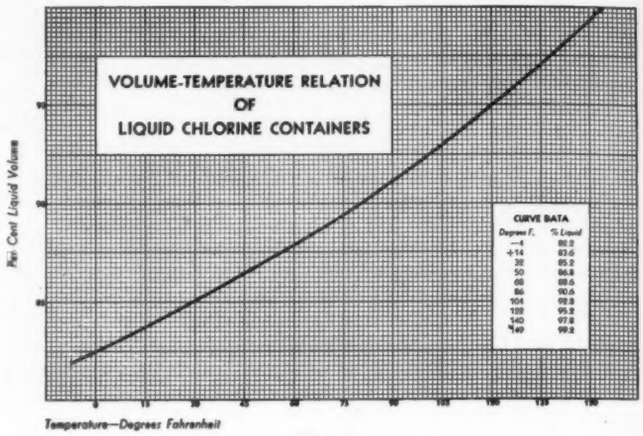


Fig. 3

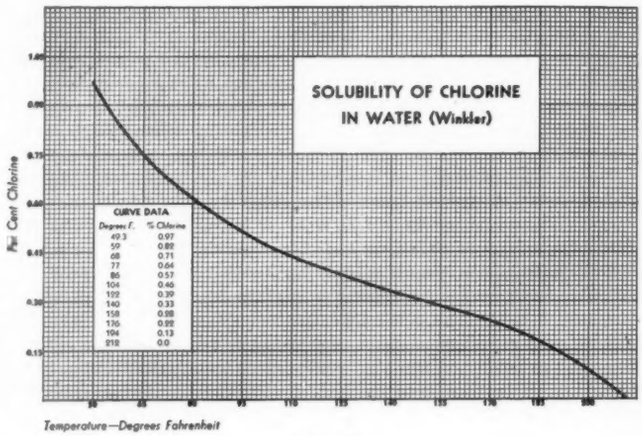


Fig. 4

A better visualization of those properties which are more serviceable can be obtained by studying the following charts and tables.

The compressibility coefficient of liquid chlorine is more than that of any other liquid element (approximately 0.0118% vol. /atm.). Its density decreases quite rapidly with increasing temperature. It is obvious from an examination of Figure 3 that above 156° F. a cylinder loaded to legal limits is subjected to hydrostatic pressure which will rupture it. Therefore, it is most important that the cylinder be kept safely below this temperature in any circumstances.

Chlorine is only slightly soluble in water. As depicted by Figure 4, its maximum solubility in distilled water is approximately 1% at 49.2° F. Below that temperature chlorine crystallizes in the form of chlorine hydrates, their composition depending upon conditions.

Liquid Chlorine Containers

Cylinders

Cylinders for shipping liquid chlorine by express, less carload, or box carload freight, are of various sizes ranging from 10 pounds net to 150 pounds net.

WEIGHTS OF 100 AND 150-LB. CYLINDERS

Net Contents	100 pounds	150 pounds
Average Tare Weight	93 pounds	123 pounds
Average Gross Weight	193 pounds	273 pounds

Minimum carloads comprise one hundred and fifty 100-pound cylinders or one hundred and eleven 150-pound cylinders.

Figure 6 illustrates the standard chlorine cylinder valve designed by the Chlorine Institute and now used by nearly all chlorine shippers. The stem "A" is of Monel metal and one complete turn in a counter-clockwise direction opens the valve so as to permit the maximum discharge of gas. A "frozen"

*From a bulletin on "Liquid Chlorine," prepared and distributed by Pennsylvania Salt Mfg. Co., March, 1936.

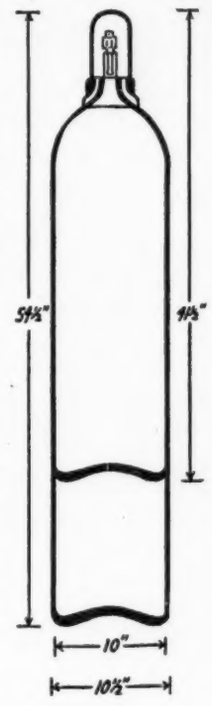
stem can usually be freed by slightly loosening the packing nut "C," tapping the top of the stem lightly, and then giving the valve wrench a sharp rap with the palm of the hand. The body "B" is a bronze and all connections to it are tightened by turning in a clockwise direction. Gas leaks around the stem can be checked by tightening the packing nut. *Under no circumstances tamper with safety plug "D."* It is below the valve seat and, therefore, cannot be controlled by the valve. Fusible metal in this plug softens at temperatures exceeding 157° F., hence cylinders should never be exposed to such temperatures for even short durations.

The valve outlet threads are standard ¾-inch hose coupling to which an auxiliary valve (containing a fiber or lead gasket) may be connected. However, these threads are bronze and are easily damaged. The clamp and adaptor shown in Figure 7 is the more practical type of connection.

Handling Cylinders

The handling of cylinders requires no expensive equipment. It is preferable that they be transported and stored in an upright position. Light, rubber-tired, two-wheeled trucks are convenient for moving them on level floors. Where cylinders have to be lifted above the ground floor a crane, or hoist, equipped with a special cradle, or carrier, should be provided in the absence of an elevator.

The maximum discharge rate of chlorine gas at 70° F. is approximately 35 pounds per 24 hours for a 100- and 150-pound cylinder. This rate may be increased by improving the circulation of air around the cylinder, or by raising the temperature. Under no circumstances should the application of heat be made directly to the fusible plug. The practical method of heating cylinders is by means of a thermostatically controlled water bath in which the temperature is limited to 100° F. Even this procedure is questionable if used in conjunction with a chlorinator because uneven temperatures prevail which in turn cause condensation difficulties. Where chlorine is used in equipment operating under cylinder pressures, it is essential that the cylinder temperature be no higher than that of the gas lines or chlorinator. Otherwise condensation will certainly occur with attending operating irregularities. (See Fig. 9.)



Cross Section of 100- and 150-Pound Cylinders

Fig. 5—Various Sizes of Cylinders

As soon as the cylinder is emptied, suction is set up tending to draw water and foreign matter back into the cylinder. This has caused several cylinder failures which could have been avoided by closing the cylinder valve as soon as the cylinder is empty.

Multiple Unit Tank Cars—Ton Containers

The multiple unit tank car is adapted for large chlorine consumers who desire a more flexible unit than the standard chlorine tank car. It consists of an underframe carrying 15 one-ton drums. Classed as a tank car, the underframe and units are subject to free freight movement both ways, freight being assessed only on the net contents of the car.

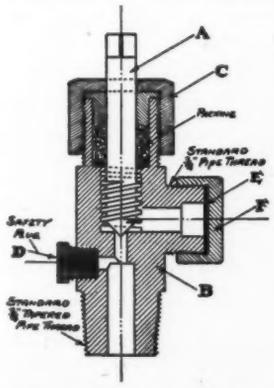


Fig. 6—Cross Section of Standard Cylinder Valve

Each of the unit containers holds 2000 pounds of chlorine. *This shipping container is authorized by the Interstate Commerce Commission for common carrier movement only as an integral part of a fifteen unit car. Multiple unit and tank cars may be consigned only to private sidings, or to approved public sidings.* (*Par. 431B I. C. C., Regulations as amended* 1933.) Where unloading conditions are ideal it is a useful package of chlorine because its units are of such size as to permit reasonable movability yet not requiring the frequent changing necessary when using small cylinders.

Each container is equipped with 2 valves, 2 internal eduction pipes, 3 fusible (157° F.) safety plugs in each end, and a removable valve hood. The valves are identical with the standard cylinder valves, except they are provided with larger internal valve openings and are not fitted with safety plugs.

Multiple unit tank cars are not recommended for plants using less than 200 pounds of chlorine per day.

Handling Ton Containers

Due to the size and weight of ton containers, special equipment is required for unloading and transporting to storage or service rooms. Stationary or movable cranes, travelling overhead rail hoists, trucks, and dollies have been employed to meet the peculiar needs of individual plants. Some type of lifting rig is necessary for use with cranes or hoists.

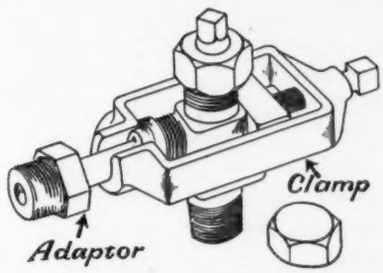


Fig. 7—Clamp and Adapter

Containers are more easily handled and serviced from a prone position. Before servicing the container should be rolled or adjusted so one valve is directly above the other as shown in Figure 12. In this position, liquid chlorine may be discharged from the bottom valve and gaseous chlorine from the top valve. Some plants concerned only with the application of gaseous chlorine prefer to up-end the containers for storing and servicing, which procedure produces material saving in floor space.

The clamp and adaptor connection previously illustrated is recommended as the most practical and flexible connection for container valves. Wrenches for operating these valves should never be longer than seven inches.

Four hundred and twenty pounds per 24 hours is approximately the maximum rate of gas withdrawal for a ton-container at 70° F., operating against 35 pounds per square inch back pressure. This rate may be increased by improving the air circulation around the container, or by raising the room temperature. *Ton containers should never be subjected to the direct application of heat because of the danger of melting the fusible plugs.*

Single Unit Tank Cars

Single unit chlorine tank cars are of two sizes, holding approximately 32,000 and 60,000 pounds of chlorine each. Located in the dome are two liquid withdrawal valves on the longitudinal axis, two gas valves on the transverse axis, and a safety valve. Each liquid eduction pipe is fitted with a vertically acting ball check which stops the flow of liquid chlorine from the car in case of unloading line breakage, sudden opening of valve, or very heavy withdrawal rates.

The withdrawal of gaseous chlorine from any liquid chlorine container causes refrigeration and subsequent pressure reduction in the container. This effect is markedly increased by the cork insulation on single unit tank cars, and consumers purchasing their chlorine requirements in single unit tank cars may find it necessary to use liquid chlorine vaporizers on their operation requiring chlorine gas. Vaporizers usually employ hot water or steam as their heat sources, and may be equipped with either open or closed jackets.

Piping and Fixtures

A copper tubing built for 500 pounds per square inch working pressure is the preferred material for connecting all chlorine containers to permanent pipe lines.

Dry Chlorine

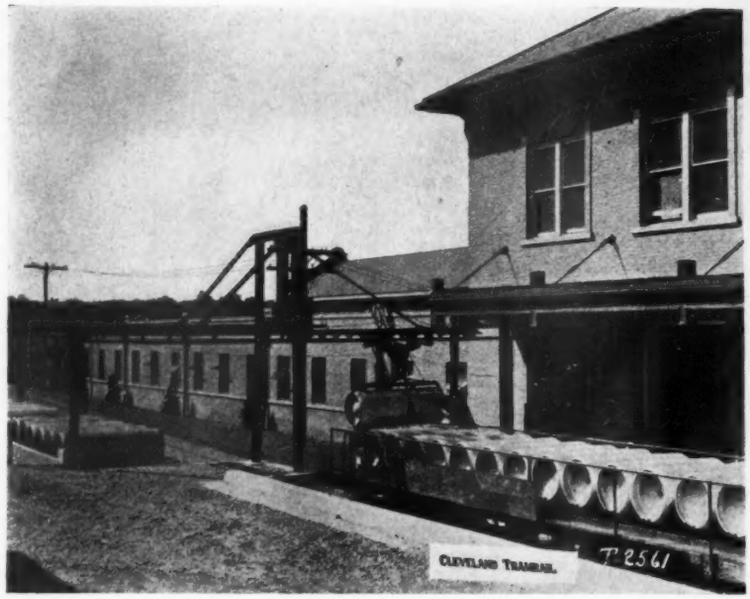
Black iron pipe is recommended as the preferable material for dry gaseous or liquid chlorine, although steel, copper, or other metal piping which will resist high pressures may be used. While standard weight pipe is satisfactory for all normal chlo-

(*Continued on page* 242)

PENNSYLVANIA SALT MANUFACTURING COMPANY

WIDENER BUILDING, PHILADELPHIA, PA.

NEW YORK • CHICAGO • ST. LOUIS • PITTSBURGH • TACOMA • WYANDOTTE



• LIQUID CHLORINE

A clear amber-colored liquid approximately one and one-half times heavier than water. Supplied in steel containers which are under pressure at temperatures exceeding 30.1° F. It is only slightly soluble in water, its maximum solubility in distilled water being approximately 1% at 49.2° F. When pressure is released, liquid chlorine volatilizes into a greenish-yellow gas which is approximately two and one-half times heavier than air. It is non-inflammable, non-explosive, and a non-conductor of electricity. Generally, in the absence of moisture it is not corrosive to common metals at temperatures below 212° F. Moist chlorine or aqueous solutions of chlorine require special equipment materials for handling.

Of the various agents for sterilizing water supplies, chlorine has proved to be the most efficacious, flexible, and economical. Under certain conditions it has the additional advantages of a sludge stabilizer, of a taste and odor eliminator, of a precipitating aid, as well as of a prolonged sterilizing agent. The quantity of chlorine required in water purification processes depends upon the quality of water, the point of application, and the object desired. Chlorine is also widely used in sewage treatment for disinfection, for B.O.D. reduction, and for odor control.

Liquid Chlorine is supplied in seamless steel cylinders in sizes ranging from 10-lb. net to 150-lb. net. They comply with every requirement of the Interstate Commerce Commission concerning specifications, retesting, loading, and maintenance of cylinders for transporting liquid chlorine. It is also supplied in multiple-unit tank cars holding 15 containers of one ton each, and in single-unit tank cars of two sizes: 32,000 and 60,000-lb. chlorine respectively.

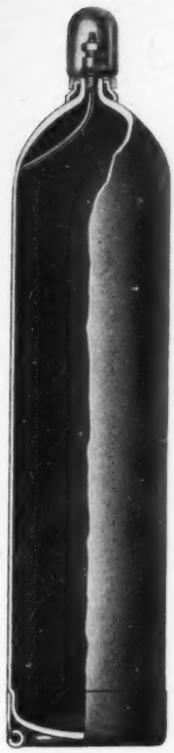
• PERCHLORON

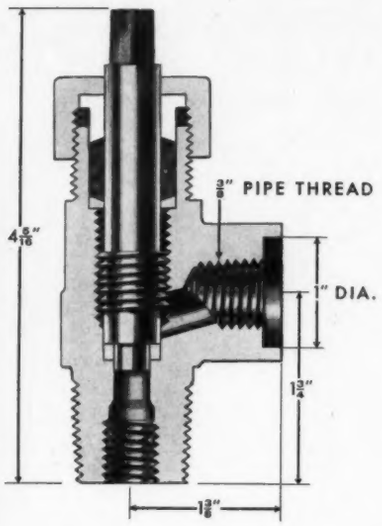
A supertest calcium hypochlorite, containing more than 70% available chlorine. It is a free flowing, fine, white, dry powder quite different from ordinary bleaching powder—being concentrated, stable, and much less hygroscopic. It weighs approximately 55 lb. per cubic foot, and 75% will pass an 80-mesh screen. Perchloron maintains 97% of its active ingredient for a 12-month period when stored in tight containers. It is quickly soluble in water. It is used as a second line of defense in water purification in time of emergency, when normal supplies of liquid chlorine may be temporarily cut off. Used for sterilizing new mains, as well as clear wells, and filters, and also in sewage treatment. Widely used by swimming pools to control and combat athlete's foot, by means of hypochlorite footbaths. It is supplied in handy-sized cans equipped with punch-and-pryup tops —12 cans to the case. Also in 75-lb. drums.

• AMMONIA, Anhydrous

A colorless liquid which, at 70° F. is .61 times as heavy as water, weighing 38.0 lb. per cubic foot. When pressure is released, it volatilizes to a colorless gas of penetrating odor, which is 0.597 times as heavy as air at standard conditions. Dry ammonia is not corrosive to the common metals, but moist ammonia attacks copper and all of its alloys, hence iron pipe and fittings are always recommended. Ammonia is exceedingly soluble in water. At 32° F. 1150 volumes of ammonia will dissolve in 1 volume of water, or 47.3% by weight.

The practical advantages of this characteristic of ammonia are observed in the employment of dry feed ammoniators in water works, and the utilization of showers for controlling serious leaks. It is used in the chloramine process, in which ammonia is applied in con-

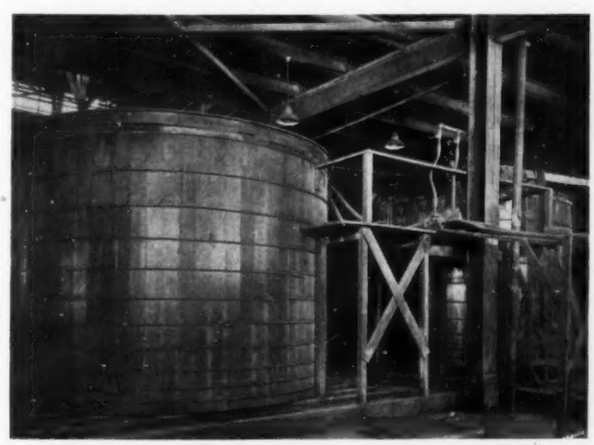




junction with chlorine to prevent the formation of chlorinous, phenolic, or medicinal taste; and for stabilizing or prolonging the sterilization action of chlorine. Ratios of ammonia to chlorine varying from 1:1 to 1:12 have been effective, while the points of application have ranged over the entire purification process. In order to prevent taste intensification, the ammonia must be applied before the chlorine. The anhydrous ammonia produced by this Company is supplied in new and improved containers which are far easier to handle and store. They are seamless drawn cylinders of special steel, exceedingly light and strong. Gas may be withdrawn with the cylinders placed in an upright position on a scale for weighing, or in a horizontal position if desired.

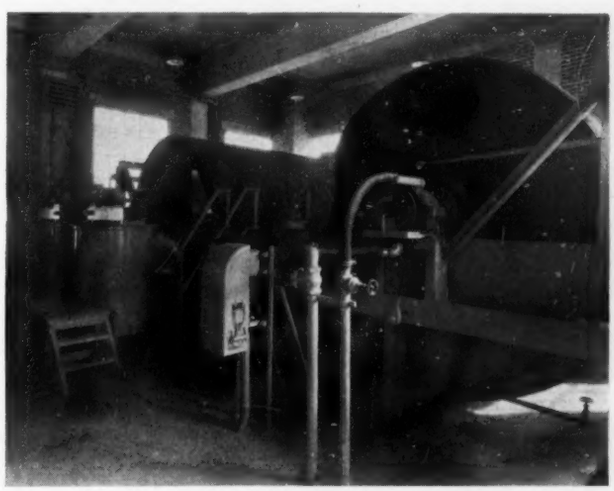
• FILTER ALUM (Sulphate of Alumina)

The principal coagulant used in water purification. Sold in all quantities from a single bag, or barrel, to carload lots, both packages and in bulk. Bags and barrels are paper lined as a protection against atmospheric moisture.



• FERRIC CHLORIDE

In liquid form it is an aqueous solution the concentration of which is governed by the outside temperature, varying from 39% $FeCl_3$ in extremely cold weather to 45% in extremely hot weather. Also available in an anhydrous form which is water-free and as near to 100% $FeCl_3$ as permitted by the impurities in the steel scrap from which it is made. Ferric chloride is a positive coagulant, producing clean-cut flocculation in economical doses. In most localities, depending upon shipping costs, ferric chloride offers tremendous economics over alum. In liquid form it is shipped in rubberlined tank cars holding 8,000 gallons and averaging 40,000 lb. of dissolved $FeCl_3$ per car. In anhydrous form it is shipped in non-returnable steel drums holding 150 lb. and 400 lb. of material respectively.



• SODIUM ALUMINATE

An alkaline compound of alumina and caustic soda which is used for softening water, and as a combined coagulant and softening agent. It is used most effectively on those waters requiring an alkali with the alum. It is usually shipped in thin steel non-returnable drums of 108 and 425 gross pounds having a net weight of 100 and 400 lb. each. 100-lb. moistureproof burlap bags are also commonly used.

• CHLORIDE OF LIME, and CAUSTIC SODA

are two other chemicals made by this Company which are used in water purification and sewage treatment. We will gladly supply further detailed information, and our technical staff is always available to assist you.

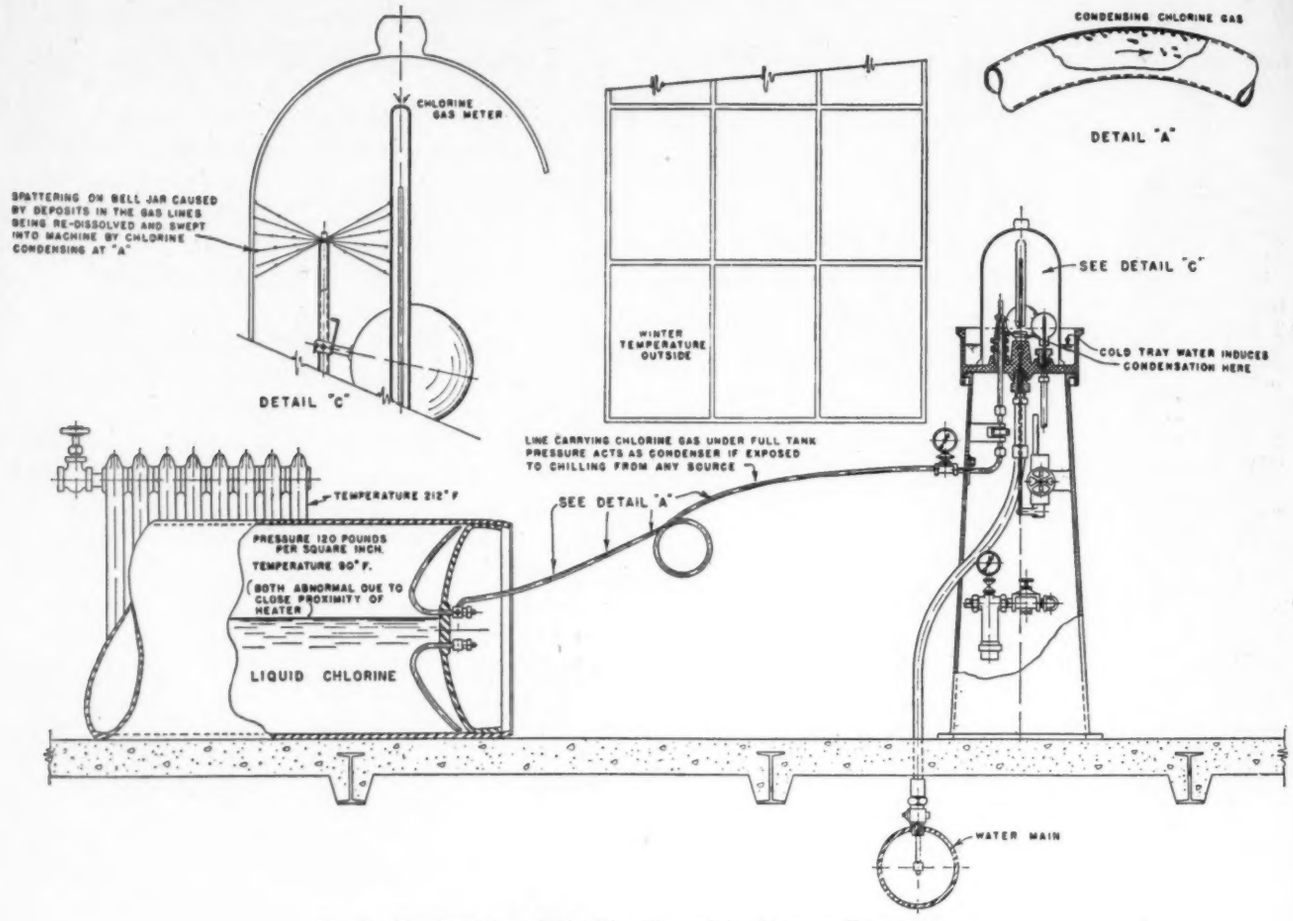

CONDENSING CHLORINE GAS
DETAIL "A"
CHLORINE GAS METER
SPATTERING ON BELL JAR CAUSED BY DEPOSITS IN THE GAS LINES BEING RE-DISSOLVED AND SWEPT INTO MACHINE BY CHLORINE CONDENSING AT "A"
DETAIL "C"
WINTER TEMPERATURE OUTSIDE
SEE DETAIL "C"
COLD TRAY WATER INDUCES CONDENSATION HERE
LINE CARRYING CHLORINE GAS UNDER FULL TANK PRESSURE ACTS AS CONDENSER IF EXPOSED TO CHILLING FROM ANY SOURCE
SEE DETAIL "A"
TEMPERATURE 212° F
PRESSURE 120 POUNDS PER SQUARE INCH
TEMPERATURE 90° F.
BOTH ABNORMAL DUE TO CLOSE PROXIMITY OF HEATER
LIQUID CHLORINE
WATER MAIN

Fig. 9—Condensation Difficulties Caused by Uneven Temperatures

rine pressures, the extra heavy variety is recommended as safer and more practical since abnormal temperatures caused by fires, mechanical strains due to displacements, and corrosion produced by the entrance of moisture are all factors which should be considered. Liquid chlorine lines should be as free from bends and obstructions as possible. Where maximum discharge rates or lifts are required, pipe friction losses should be reduced by using lines of ¾ inch or more in diameter.

Hard rubber pipe is satisfactory for chlorine gas, but should never be used for conveying liquid chlorine. Pressure should not exceed 50 pounds and 80 pounds for the standard and extra heavy hard rubber pipe respectively. *Lines conveying gaseous chlorine should be run on a continuous upgrade in order that condensed (re-liquefied) chlorine will run back into the container.* Where this is impractical, drip legs should be provided in the low points of the pipe line. These legs should terminate in pockets which will assure evaporation of the liquid chlorine. *Blow-off cocks or other bleeding arrangements are not recommended since they are both dangerous and unnecessary.*

Pipe joints may be made with standard couplings, unions, or flanges. Standard ammonia flanges are preferable, since their use permits easy inspection and repair to lines. Gaskets should be of lead or asbestos composition. Only special valves for chlorine service should be employed. Usually, the body is of steel or special bronze, and the stem is of Monel metal. Graphite coated asbestos and rubber covered asbestos are recommended for packing. Flanged valves are preferable. Gauges should be of the diaphragm type for chlorine service. *Equipment and lines carrying dry chlorine should not be exposed to excessive heat.*

Wet Chlorine

Wet chlorine is very corrosive to all of the common metals. Materials contacting it must be of earthenware, glass, rubber, one of the special alloys, or noble metals. The handling of wet chlorine is an individual plant problem and specific recommendations can be made only after a survey and study of the various factors involved.

Handling Chlorine Leaks

(The safety information in the following paragraphs has been taken largely from Sale Practices Pamphlet No. 71 of the National Safety Council, as recommended for revision by The Chlorine Institute in December, 1935. For more complete safety information write the National Safety Council, 20 North Wacker Drive, Chicago, Illinois.)

The ventilation provided for the chlorine room, mechanical or otherwise, should be of such nature as to remove and dissipate the gas with the least injury to persons and property.

Stand leaking container upright if possible. This will prevent the escape of liquid chlorine and under these conditions vaporization diminishes rapidly as natural chilling takes place and the escape of chlorine into the air will then be very slow. Ton containers have two valves, and in case of a leaky valve, the container should be rolled so the valves are in vertical plane with the leaky valve upward. In this position the valve will leak chlorine gas, not liquid chlorine.

In case of accident indoors, every effort should be made to remove the leaky container outside the building. *Water played on a gas tank will not stop the leak.* Water in large quantities played on a cylinder gas leak will assist in diluting and dissipating the gas. Water played on a liquid leak may provide

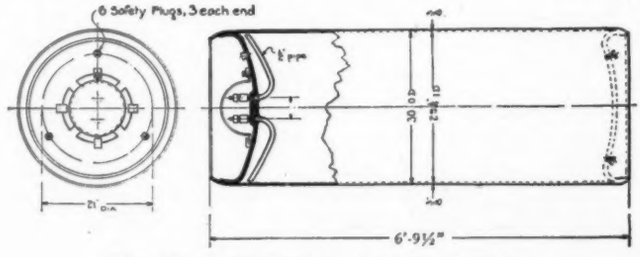


Fig. 12—Cross Section of a Ton Container

chlorine hydrate from which the evaporation of gas is slow. These operations should only be undertaken by a competent person wearing an approved gas mask in good order. When a pond or large body of water is nearby, the leaking container should be submerged in the water. Loose earth, cement, lime (both slaked and unslaked), and heavy textiles (both wet and dry), such as bagging and felt, will act as an absorbent or blanket.

It is illegal to ship a defective or leaking chlorine container. If there is an accident, telephone the car owner or nearest chlorine plant for assistance. The telephone numbers and residence addresses of the nearest chlorine plant organization members should be posted in the office of the person in charge of the handling of chlorine in the plant of the user, and in the office of the manager.

Gas Masks

It is imperative that some form of protection be provided for emergencies. Several types of gas masks approved by the U. S. Bureau of Mines and suitable for high concentrations of chlorine are available. For this purpose, a sufficient number of suitable gas masks should be on hand and located at a readily accessible point outside the area likely to be affected in case of accident. The instructions accompanying a mask concerning its care and use should be obeyed implicitly. Everyone who is in danger of being accidentally exposed to high concentrations of chlorine should be provided with a gas mask, preferably to be used by no one else. He should be familiar with the instructions accompanying it and trained to hold his breath and to put the mask on quickly and properly. Periodic strict inspection and maintenance of approved gas masks are essential.

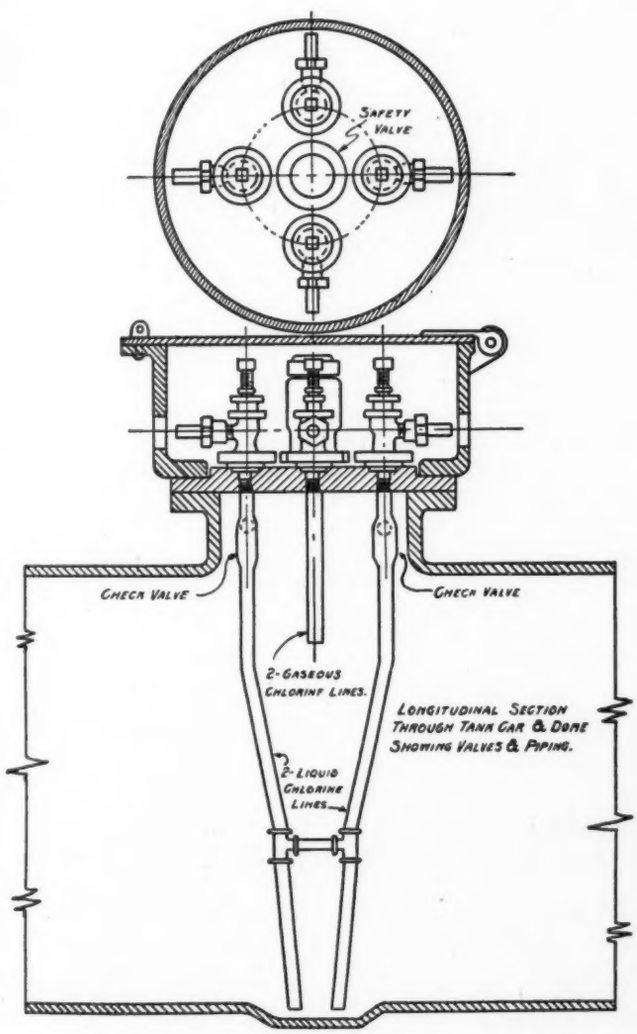
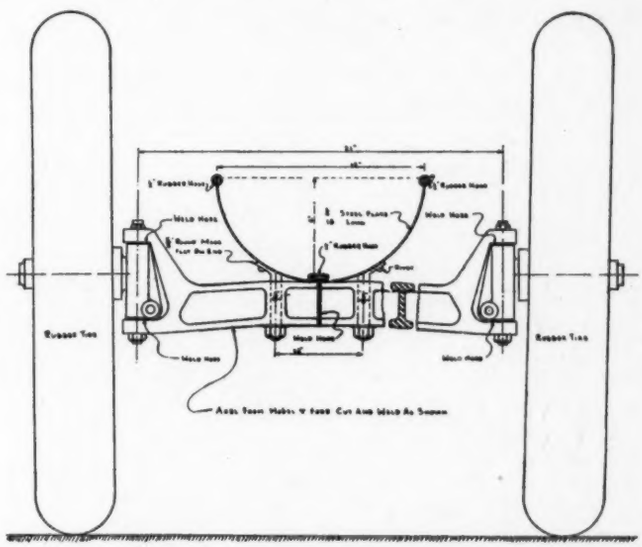


Fig. 17—Details of Dome and Inner Shell of Single Unit Chlorine Tank Car

Safety Cylinder Handling Carriage

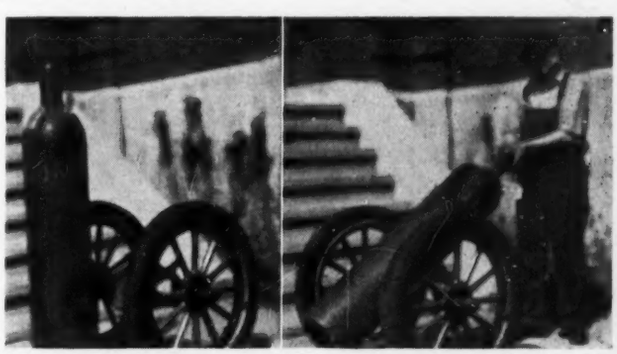
The accompanying pictures and detail sketch illustrate a novel, efficient and inexpensive carriage for transport of cylinders containing chlorine, ammonia or other compressed gases.

The device was designed and constructed from the wheels and front axle of what was once a Model "T" Ford automobile. Its ease of handling is self evident and its use saves many a "weak back" and avoids dangers of injury to the "strong men" around water and sewage plants.



Model "T" Cylinder Carriage
Unique Carriage Designed for Cylinder Handling at the Water Purification Plant of the Philadelphia Suburban Water Co.

To Edward J. Jenkins of the Philadelphia Suburban Water Company, Bryn Mawr, Pa., we are indebted for the illustrations of this unique cylinder truck which was developed in the above plant under his supervision.



In Position *Ready to Ride*

THE COLUMBIA ALKALI CORPORATION

Offices and Plant: Barberton, Ohio

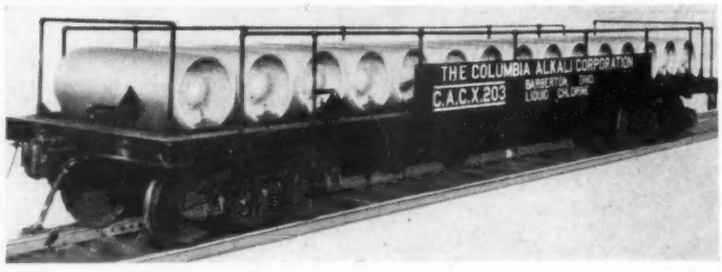
BRANCH SALES OFFICES

New York Chicago Boston St. Louis Pittsburgh
Cincinnati Cleveland Minneapolis Philadelphia

With its plant centrally located and served by four railroads, COLUMBIA offers excellent service to all consuming centers, by direct shipment from plant on carload quantities and through conveniently located distributors on less than carload orders. COLUMBIA maintains a Technical Service Department, its staff composed of experienced chemical engineers, each of whom specializes in one or more COLUMBIA products. The complete facilities of COLUMBIA'S Research, Engineering and Plant Technical staffs are at the disposal of this department whose sole purpose is to cooperate with users of COLUMBIA products on their applications, qualities, and methods of handling to meet individual requirements. Analyses and samples are available to interested concerns without cost and on request, a member of the Technical Service Department will call for personal discussion without obligation. The COLUMBIA Technical Service Department is particularly well qualified to assist customers in the design, installation and operation of equipment or processes involving the use of Liquid Chlorine.

COLUMBIA LIQUID CHLORINE

SHIPPING UNITS ● **30 ton single unit cars** ● **16 ton single unit cars** ● **15 ton multiple unit cars** ● **150 and 100 lb. cylinders**



COLUMBIA Liquid Chlorine is produced in a modern plant with the most improved equipment, assuring the consumer a uniform product of full strength and purity.

The equipment for the distribution of COLUMBIA Liquid Chlorine conforms to standards of the Interstate Commerce Commission and the recommendations of The Chlorine Institute. The latest and best type of cylinders are used. The COLUMBIA 100-pound cylinder is seventeen pounds lighter than others commonly used, and the 150-pound COLUMBIA cylinder is twenty-nine pounds lighter than the ordinary type of cylinder used. This is due to the fact that modern type pressed steel construction is used. Perfect valves are of vital importance to efficient and safe handling of Liquid Chlorine. Cognizant of this, COLUMBIA removes and reconditions all valves every time an empty Chlorine container or cylinder is received at COLUMBIA's plant. The valve seats are reground. Any worn or defective part is replaced. The packing is changed for new. After reassembly, follows thorough inspection and testing by immersion in water under a pressure greater than is required in use. In fact, every precaution that engineering skill can devise is taken to assure consumers of COLUMBIA Liquid Chlorine maximum valve efficiency.

COLUMBIA LIGHT SODA ASH

99-100% Na_2CO_3 (58% Na_2O)

PACKAGES ● **Bulk** ● **Paper Bags, 100 lbs.** ● **Burlay Bags, 200, 300 lbs.** ● **Barrels, 300 lbs.**

Recommended for its purity, uniform density, free-flowing properties, and rapid solubility. Preferred by many experienced chemists for water treatment. COLUMBIA Soda Ash is also produced in Feather and Dense grades for specific uses.

OTHER COLUMBIA PRODUCTS

SODA ASH
LIGHT FEATHER DENSE

CAUSTIC SODA
SOLID FLAKE POWDERED LIQUID

SODIUM BICARBONATE
U.S.P. TECHNICAL AND GRANULAR

MODIFIED SODA

CALCIUM CHLORIDE
FLAKE LIQUID SOLID

SOME PRACTICAL ASPECTS OF HANDLING CHLORINE

By CHRIS F. BINGHAM*

Barberton, O.

There appeared in the September, 1935, issue of the Journal of the American Water Works Association a valuable report, dealing with chlorine, by the Committee on Chemical Hazards in Water Works. This paper is intended to record various practical experiences in chlorine handling and opinions that in their nature had no place in the above committee report. However, the writer will quote freely from the report, where deemed advisable, and recommends that those interested procure a copy of the journal containing it.

Properties of Chlorine

Chlorine gas is approximately two and one-half times as heavy as air at normal temperature and pressure, and hence, leaking chlorine, tends to settle and collect in low places and on the floor of an enclosed room.

Chlorine is neither flammable or explosive. The dry gas does not attack iron, copper, or lead at ordinary room temperature. However, in the presence of moisture it is very corrosive and combines readily with most metals except those classed as the "noble" metals and special alloys. It is important to note that even the dry gas becomes very corrosive at temperatures above 300 degrees F. and is likely to become so at temperatures as low as 195 deg. F.

Chlorine Lines

Rubber and the noble metals are sufficiently resistant to the action of wet chlorine to be satisfactory materials to handle either the moist gas or water solutions. Liquid chlorine in itself cannot, however, be used with hard rubber. During the last year and a half plant tests have been made in Richmond to determine the resistance of asbestos-cement pipe to chlorine solutions. As a result, the prechlorination and copperas-chlorine solution systems have been rebuilt using two and one-half inch "Transite" Class "B" pipe and Class "S" elbows. So far, this installation has given excellent service, the only difficulty encountered was due to its brittleness and the lack of sufficient mechanical support—a few sections of the pipe being broken by strains before adequately supported. The chlorine solution seems to "wet" the inside of the pipe to a depth of ⅛ to 3/16-inch and then stop, no further change was noted in the experimental installation or in the new permanent installation after two months of heavy use.

Extra heavy iron pipe with wrought iron fittings and litharged joints should be used for the chlorine pressure lines. Litharge that has been opened for some time seems to form a carbonate coating on the particles which result in a never-hardening and oily joint compound which will allow the joint to leak probably. Only new litharge is recommended. Care taken in the correct installation of pressure feed lines is a thousand fold repaid. Ammonia valves (of steel) have been used in the chlorine pressure lines at Richmond with satisfactory results, but where possible the standard Chlorine Institute ton container valve has been used because of its convenience, economy and superior construction. In general chlorine needle valves should have either Hastelloy "C" or Monel Metal stems, and joint valve bodies may be constructed of steel, brass or Hastelloy "C."

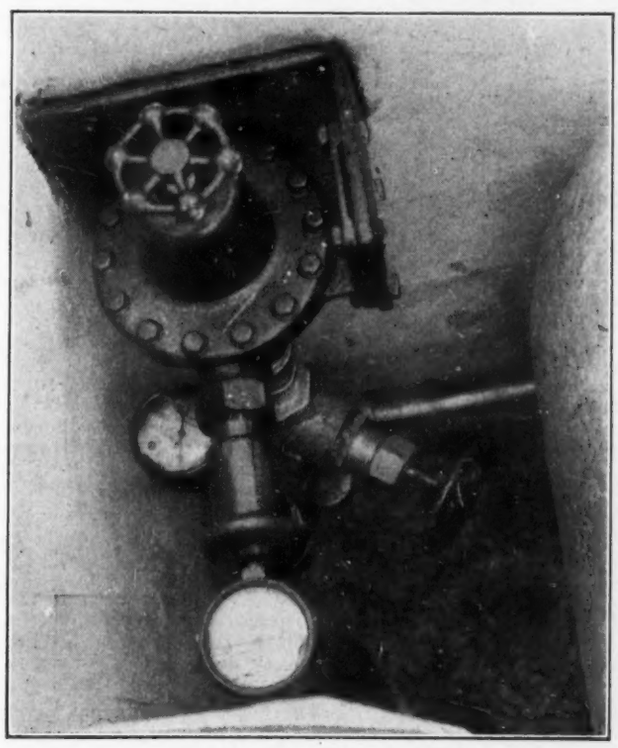
Soft copper tubing connections (cadmium plated) are used in connecting the one-ton chlorine containers to the piping system. We specify that a small wrench "hold" be milled on the bushing on the tubing, to allow holding the tube at the joint during tightening of the coupling. This, to prevent wringing off the tube at that point. The tubing becomes quite hard and rigid after continued service, but its ductility may be renewed by heating slowly to a dull red heat and quenching in water—the customary method of copper softening.

Hard drawn copper fittings and pipe of the "Streamline" type also have been used with essentially *pure* silver as the solder instead of the regular solder, furnished for such pipe, which chlorine attacks. A silver coin will serve as satisfactory solder. High copper content brass fittings have been used with this type of pipe also and seem to work entirely satisfactorily.

Avoiding Condensation Troubles

The gas feed lines should, if possible, always be warmer than the chlorine containers to avoid condensation (re-liquifaction of chlorine) and consequent problems. These lines should also be run on a continuous upgrade from the containers in order that the condensed liquid chlorine will flow back to the containers. Such theoretical conditions cannot always exist practically and, in cases where this is impossible, drip-legs should be provided at every low point on the pipe line—especially so near the chlorinators. Blow-off cocks or other bleeding arrangements are not recommended since they are both dangerous and unnecessary. If the drip legs are so located that the room temperature does not keep the condensate vaporizing at a satisfactory rate, additional heat may be applied by warming with a 100-watt electric bulb permanently installed beneath the leg. The size of the leg varies with the conditions, but it is recommended to be 1¼ times as large as the volume of the pipe line leading from the chlorine container to the leg.

Chlorine reacts with grease and oil to form voluminous frothy substances; with gasoline and other petroleum distillates to form solid complex chlorinated hydro-carbons. Alcohol and ether, even in traces, are converted to solid waxy hexachloroethane. It



One of the Reducing Valves (Looking Down) on the Chlorine Feed Lines. It Is Located on the Manifold Just Beyond the Containers in the Outside Gassing Chamber

is important, therefore, that all grease, moisture, etc., should be thoroughly removed from chlorine lines during their erection. Methane derivatives, chloroform, wood alcohol, and carbon-tetrachloride are the only safe chlorine equipment cleansers to employ.

Whereas, drip legs are very helpful, condensation in chlorine lines should be avoided. If the gas leaving the container drops only a few degrees in temperature it will condense into a liquid in the feed lines and find its way into the chlorinators, with its consequent troubles. This condition can best be avoided by reducing the pressure at the containers to the lowest point permissible for the proper operation of the machines. In fact, if

*Plant Supt., Div. of Filtration, Dept. Public Utilities, Richmond, Va., at time of preparation of this article. Now Tech. Service Engr., Columbia Alkali Corp.

Handy Light Weight Safety Truck for Cylinder Handling (Courtesy Carl Leipold, Winnetka, Ill.)

the line pressure be kept at 40 pounds per square inch or less no condensation can occur in the lines except at extreme cold temperatures. In Richmond, by keeping the reducing valves (in duplicate) set at 35 pounds per square inch, no liquefaction has resulted, although the chlorine feed lines are 400 feet long and the containers are in compartments outside of the plant which get quite warm in summer and also are artificially warmed in cold weather—an ideal condition for condensation in the feed lines.

Chlorine, in distilled water, at 49.2 deg. F. will form chloral-hydrate, commonly referred to as "chlorine ice." This condition is frequently found in the trays of vacuum type chlorinators during cold weather; but may be overcome by placing an electric light under the tray of the chlorinator. At the same time, reducing the water flow through the tray is also helpful. Since the solubility curve is a very sharp one a rise of only one or two degrees of the water is sufficient to do away with the trouble.

Container Temperatures and Pressures

The per cent of container volume occupied by liquid chlorine in the containers, when loaded to the limit permitted by the Interstate Commerce Commission regulations, is such that at 153.9 deg. F. the cylinder becomes completely filled due to the expansion of the liquid chlorine. Liquids do not have the compressibility or cushioning effect possessed by gases hence any further increase in the temperature will cause enormous pressure in the containers. For this reason, fusible plugs are provided which are intended to soften at slightly above this temperature and thus relieve the dangerous pressure. It is important, therefore, to keep the cylinders below this temperature regardless of the amount of chlorine that they may contain. Experience at the Richmond plant justifies this warning.

There are several practical precautions suggested by the above facts. Cylinders should never be directly heated by flame, steam or even electrical means that can exceed 160 deg. F. To avoid such hazard, warm air from the building is blown through an underground pipe to the containers which are housed in compartments outside of the plant. Secondly, a full cold chlorine cylinder has a lower pressure than one at room temperature; hence, if they are connected together as on a header, the cold cylinder will actually draw in chlorine. If the valve is then closed the overloaded cold cylinder may cause trouble when it becomes warm, even to room temperature. Hence, cylinders should be brought to about the same temperature before being connected together. As another example, the re-loading of containers thought to be empty, is absolutely forbidden unless under technical supervision.

If gas is drawn from a container, the pressure within the container will be reduced. If a constant supply of gas at constant pressure is to be maintained, then heat must be applied to the liquid in the container. The more rapidly the gas is removed, the more rapidly heat must enter. This is usually accomplished by increasing the room temperature. If instead of adding heat, the container is cooled—the pressure falls. This is why a leaking cylinder should be cooled as rapidly as possible. Different opinions exist as to the maximum rate that gas may be drawn from cylinders. Experiments at Richmond have indicated that as much as 800 pounds per day may be drawn from the standard one ton container, in the summer when indoors, with pressure maintained on the gas line at not less than 30 pounds per square inch. However, 400 to 450 pounds per day is about the maximum successful continuous rate of supply from these containers. With the 150 pound cylinder the rate is about 30 pounds per day. Increasing the room temperature and providing air circulation will increase the rate of gassing. Especially so with a full cylinder because there is then a large area of the liquid exposed to the sides of the warmed container. Adequate air circulation is a considerable aid in maintaining sustained gassing rates.

Handling Containers

Containers are built of steel and may be safely handled with care. Dropping or bumping containers is extremely dangerous, and facilities used in handling should be carefully arranged to prevent such rough treatment. Hoisting is to be avoided if possible. Low, rubber tired trucks are preferable if conditions allow. A rubber tired light weight hand-truck for 150 pounds cylinders, first used by Carl Liepold at Winnetka, Ill., plant has proven both safe and convenient. The overhead monorail system used in Richmond for ton containers, involves the use of a lifting hook used to reduce space and suitable for low head operation on such a system. Out of doors storage is provided in racks, the enclosed section being the warmed gassing chamber. The maximum chlorine temperature yet found in these stored containers is 108 deg. F. or a pressure of 160 pounds which is amply safe. In warmer climates it may be well to shield stored containers from direct heat of the sun.

Chlorine may be safely stored indoors. Having the containers in operation mounted near the control machine undoubtedly has its advantages. In small installations, having in storage or in use only a few 150 pound cylinders, this risk is not serious and the practice is to be recommended, but when larger quantities of chlorine are necessary the advantage of the out of door storage and gassing chamber, with only the chlorine feed lines and the machines in the building, is certainly evident.

Ventilation Facilities and Leak Handling

When storage and operating containers are indoors adequate and reliable ventilation is essential. Exhaust air ducts draining

The Chlorine Leak Tester

air from the room should intake at the *floor level* and a fan forcing air into the room should drive the chlorine atmosphere directly out of the building. Where steam is available, a suitably designed ejector system, with discharge to a sewer or stack, is perhaps the best disposition of the escaped chlorine.

The use of neutralization tanks containing caustic, or attempting to stop a leak by spraying water on the leak, or cooling with ice and salt, while theoretically correct, are of doubtful practical value. Practically it has been found at the Richmond plant that the best disposal is by submerging the cylinder, as for example, in the raw water flume, or other convenient large body of flowing water. "Dry Ice" (solid carbon dioxide), is the only method used successfully in cooling a cylinder to stop a leak by sufficiently reducing the gas pressure.

A suitable number of gas masks, of a design approved by the U. S. Bureau of Mines, should be readily available in a convenient location, and all employes should be trained in the correct procedure in putting on the masks. There is quite a prejudice among a large number of operators against the use of a mask in stopping small leaks. Contrary to general statements otherwise, that chlorine exposures produce no cumulative effects, the writer has noted cases of men repeatedly exposing themselves to small concentrations and have ended up with irritations such as results from a heavy concentration. It is well to note that the life of a canister type gas mask of the soda lime-activated charcoal type, depends not only upon the extent to which it is put to active service, but upon the storage conditions. Such canisters deteriorate rather rapidly when left open to the air and, therefore, the bottom opening of the canister should be kept sealed with the plug or disc supplied by the manufacturer. The useful life of a canister cannot be predicted and a fresh canister should always be available. Canisters should be replaced periodically, regardless of use.

Remember three simple rules in using a gas mask:

1. Never use where there is any danger of a deficiency of oxygen.
2. The life of the canister is an unknown quantity.
3. Any gas mask job is a *two-man* job.

Even small chlorine leaks are dangerous and should be stopped immediately. A chlorine leak may be readily located by means of aqua ammonia. The best procedure so far found in Richmond consists of the use of a "blow-bottle" here illustrated. This is a bottle of suitable size to carry in one hand conveniently. A rubber atomizer bulb is attached and permits the operator to blow ammonia fumes from the bottle while holding the outlet nozzle near the suspected leak. This outfit can be easily manipulated with one hand.

Flexibility of Chlorinator Service

Chlorine control machines are relatively expensive, yet ample reserve against extra demands or repairs is absolutely essential in every plant. To reduce the number of machines needed, and yet leave reliable reserve at the Richmond plant has been installed a most successful transfer system. Three points of chlorine application before filtration and four control machines are available on the transfer. By means of the transfer system, the opening of a valve permits any or all of the four chlorinators to supply any or all of the three points of application. By changing hose connections two additional control machines may be substituted thus making six machines almost immediately available at any point of chlorine application. Thus six machines give as reliable service as would ordinarily necessitate nine machines.

The author wishes to gratefully acknowledge his indebtedness for the suggestions and criticisms of: M. C. Smith, Chairman of the A. W. W. A. Committee on Chemical Hazards in Water Works; L. H. Enslow, Research Engineer of the Chlorine Institute, and Editor of WATER WORKS AND SEWERAGE, and to Carl Liepold of Winnetka, Ill.

MUD-BALL AND HARD-SPOT BREAKER*

By HOMER W. SCHUMPERT

Superintendent of Water, Light and Sewage, Newberry, S. C.

Like many other plants, our filtration plant at Newberry has been troubled with mud-balls and hard-spots in the sand beds.

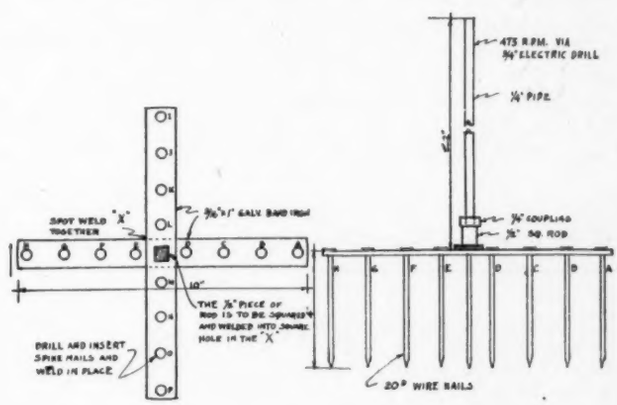
After trying many schemes and devices, that to be described seems to be of sufficient value to justify its publication.

The "Mud-Ball Breaker," as we call it, is here sketched. It is made from two 10-in. pieces of cross-arm bracing, for electric-line poles, welded in the form of a cross and attached to a shaft of ¼-in. steel pipe. The "tool" is turned by a light weight hand motor such as is used for electric hand-drills.

Through the pieces of bracing (1 in. wide by 10 in. long by 3/16 in. thick) are drilled holes to take 20-penny nails and a square hole (½ by 1.2 inches) is cut at the center of the cross (see sketch). The nails are welded in at their heads and the strips of bracing are spot-welded together at the center. A 2-in. piece of ½-in. steel rod is squared at the end and welded into the square center hole. A coupling and reducer connect the rod and the shaft of ¼-in. pipe. This shaft, 2 ft. long, fits into the chuck of the standard ¾-in. electric hand-drill which has a free-speed of 475 r.p.m.

Using the Filter Wash Tool

The water level is lowered in the filter until only 1 or 2 in. stands above the filter bed. Then the operator plugs in the cord of his tool (drill) and climbs down into the filter troughs. He starts the tool rotating at the 475 r.p.m. speed and proceeds to attack the mud-spots with it for about 6 minutes, employing a churning (up and down) motion of the whirling head. Then the filter is washed as usual.


475 R.P.M. VIA ¾" ELECTRIC DRILL
¼" PIPE
SPOT WELD "X" TOGETHER
¾" COUPLING
½" SQ. ROD
10"
THE ½" PIECE OF ROD IS TO BE SQUARED AND WELDED INTO SQUARE HOLE IN THE "X"
DRILL AND INSERT SPIKE NAILS AND WELD IN PLACE
20P WIRE NAILS

Details of the Mud-Ball Breaker

We tried experiments thinking it possible to improve this device, but in the end we believe the sketched tool, as simple as it is, does the best job without the "improvements." When the spinning cross arms strike a wall the tool merely bounds away without damage. The whole assembly is light, inexpensive, and (most important) it does the job.

[Mr. Schumpert comments by letter: "If you do not believe that the job is easily and effectively done, then just try it yourself."—ED.]

**Water Works and Sewerage—July,* 1938

ARMCO CULVERT MFRS. ASSOCIATION

MIDDLETOWN, OHIO

FABRICATING PLANTS THROUGHOUT THE UNITED STATES AND CANADA

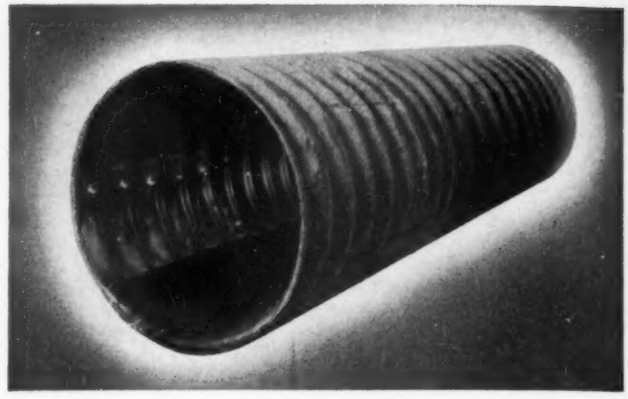
ASBESTOS BONDED ARMCO SEWER PIPE

MULTI PLATE PIPE AND ARCHES

PERFORMATED METAL PIPE • FLUMES

BIN-TYPE RETAINING WALLS

DRAINAGE GATES • STANDARD FULL-ROUND AND PART-CIRCLE CULVERTS

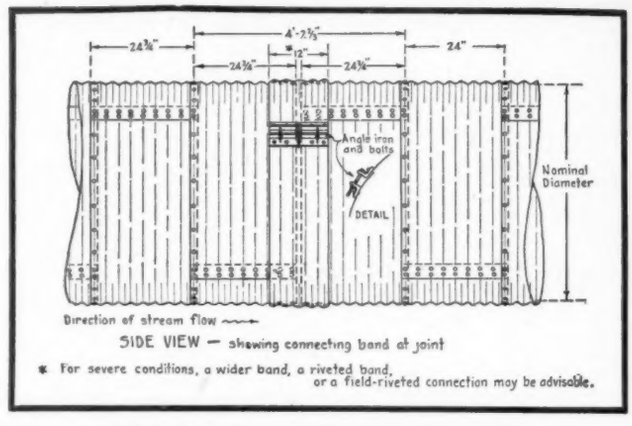


Asbestos Bonded Armco Sewer Pipe.

ARMCO SEWER PIPE

A full-round corrugated pipe made of galvanized ARMCO Ingot Iron. Paved in the bottom and fully coated with a special bituminous material which is mechanically bonded to the pipe by means of asbestos fibres embedded in the galvanized coating.

Armco Sewer Pipe is quickly available in diameters from 8 to 96 inches, including connecting bands and standard or special fittings. Individual lengths up to 20 feet. Write for 48-page illustrated book on sewers containing useful design information.



Fabrication details of Armco Sewer Pipe.

RECOMMENDED GAGES FOR ASBESTOS BONDED ARMCO SEWER PIPE

	DEPTH OF COVER (H), FEET								
Diam. D Inches	1 — 2	2¼ — 7	7½ — 10	11 — 15	16 — 20	21 — 25	26 — 30	31 — 35	36 — 40
12	16	16	16	16	16	16	16	16	16
15	16	16	16	16	16	16	16	16	16
18	16	16	16	16	16	16	16	16	14
21	16	16	16	16	16	16	16	14	14
24	16	16	16	16	14	14	14	14	14
30	14	14	14	14	14	14	12	12	12
36	14	14	14	14	14	12	12	10	10
42	14	14	14	12	12	10	10	8	8 *
48	14	14	14	12	12	10	8	8	8
54	12	14	12	10	10	8	8	8	8
60	12	12	* 12	10	8	8	8	8	8
66	12	12	12	8	8	8	8	8	8
72	10	12	10	8	8	8	8	8	8
84	8	10	8	8	8	8	8	8	8

Note: The gages shown are based on a maximum deflection of 5% for the following loadings:
1—Live Load = H 20 + 50% impact = 24,000 lbs. concentrated surface load.
2—Dead Load = Embankment (ordinarily heavier than ditch loading.)

*** For pipe below heavy black lines consult an Armco engineer for installation instructions.**

PART II. SEWERAGE

Whereas, this section is devoted almost exclusively to Sewerage, it was not possible to segregate material, which pertains to Water as well as Sewage, except at the expense of duplication.

The Water Works Section will be found to contain considerable material of direct bearing on Sewerage. Such, for example, are articles on "Metering"; "Pumps and Pumping"; "Elimination of Check Valve Slain"; "Practical Hydraulics"; "Practical Electricity in the Plant"; "Chlorine and Its Safe Handling," et al.

See also "Water Hammer Correction," by Henry Ryon in the Magazine Section of this issue.

MAINTAINING A SEWERAGE SYSTEM*

By GEORGE E. FINCK

Engineer, Bureau of Sewers, Baltimore, Md.

The extent of maintenance required to keep a sewerage system in successful operation may be traced more or less to the following causes: (1) Poor Design and Construction; (2) Depreciation and Misuse.

The amount of maintenance necessary on account of depreciation due to wear and tear is usually not great, particularly if the system is new, and of good workmanship and material. A frequent source of trouble, however, if not guarded against will result from the tapping of sewers for extension of house connections. No sewer in the City of Baltimore is permitted to be tapped unless a permit from this Bureau has been issued, and the *work must be done under the supervision of a Department Inspector* and by a qualified pipe layer. Noisy and broken manhole covers add a great deal to general maintenance work and numerous inlet heads have to be repaired and replaced from time to time, all of which is the result of increased traffic.

Dealing With the Root Problem

To have low maintenance costs, good construction is essential under careful and competent inspectors. A very important factor in this respect is the making of tight joints for the exclusion of ground water and to guard against the entrance of tree roots. Numerous chokages in the sanitary sewers of Baltimore are due to the roots of poplar and willow trees. The roots of oak and similar shade trees do not seem to give any trouble. In each case where the sewer becomes chocked because of tree roots, and it is necessary to uncover the sewer, the joints through which the roots have passed are made over with great care in the following manner. A ring of jute is inserted in the bell of the pipe the same as when the usual Portland cement joint is made. Then puddle clay, to which has been added a liberal quantity of coarse salt is packed over the jute to within one-half inch of the end of the bell. On top of this is placed a mortar of cement and sand. This type of joint has proved very effective against the entrance of tree roots. The planting of poplar trees on public highways of the city of Baltimore is now prohibited.

The misuse of the sanitary sewerage system is probably the principal contributing factor to high maintenance costs. Although sewers are intended for definite purposes, they often are used as a means of disposing of materials intended for the rubbish pile. The following are but a few of the objects which have been taken from Baltimore sewers from time to time: Bricks, flat irons, dish pans, broom handles, bottles, garden hose and occasionally small dead animals. The only conceivable means by which such objects can be introduced into the sewers is by the unauthorized removal of manhole covers and through sewer cleanouts on the plumbing lines.

The amount of maintenance required for the storm drainage system can be held to a minimum if streets are frequently cleaned and the debris removed before it is washed into the drains, where it usually has to be removed at considerable cost. Present day heavy traffic has brought about the necessity for prompt removal of snow. The practice generally followed is to dispose of it into the storm drainage system. It is usually mixed with debris and after the snow has melted in the drains this debris remains behind and has to be removed. It is essential that only large drains should be used for snow removal and great quantities of water used for flushing purposes.

[*Note.—In the magazine section of this issue appears another article on "Sewer Maintenance," by Joseph H. Le Chard, Chief Engineer and Supt., The Atlantic City Sewerage Co.]

Solution of the Oil Dumping Problem

A serious problem confronting engineers in charge of sewerage systems relates to the disposal of gasoline and oil from automobile crank cases into the storm drains. Many cities have had serious explosions as the result of this practice. The City of Baltimore has to a great extent overcome the problem by the passing of an ordinance requiring that waste oils, greases, crank case drainings and similar products be stored on the premises in tight steel containers. The material is then collected and disposed of periodically under direct control of City authorities. This arrangement has proved satisfactory because it provides garages and similar establishments with a way of disposing of oils and greases, as the City has previously found it almost impossible to police all garages to enforce an existing ordinance which prohibited the discharge of oil and gasoline into the sewers. [A copy of the Baltimore ordinance, covering oil disposed, can be had by addressing the author.—Editor.]

It has been found that the large storm drains require little if any cleaning as they are usually well flushed at every heavy rain. Inlets require periodic cleaning to remove decomposing material and an occasional dead animal. Disinfectants and deodorants are used at times when odors are detected in the inlets.

The principal source of trouble in a sewerage system is usually confined to the smaller sizes, namely 8 inches and 10 inches in diameter. When the larger sewers need cleaning it is usually due to wastes from industrial plants.

Tools and Equipment

The proper selection of cleaning tools plays an important part in helping to decrease maintenance costs. There are two types of cleaning rods in use in Baltimore. Jumbo rods No. 10 used to clean out storm water drains are of wood, 3 ft. in length and about 2 inches thick. They have strength and are light enough to float on the water while being forced through the drain. Other rods used to clean sanitary sewers are 4 ft. long and are 1⅞x1⅞ inches in cross section. Other tools such as scoops, root cutters, etc., are essential. Flexible steel cables with steel rollers at the end are used to clean house sewers.

Flexible Sewer Rods

A new type of equipment has recently been purchased for removing obstructions in main line sewers. It consists of 3 ft. flexible steel rods which can be coupled together with connectors especially designed for the insertion of a proper tool for twisting purposes. The flexible sectional-rod cable, thus made up, is run through a 1½-in. pipe guide rigidly fastened in a vertical position in a manhole, the lower end of which guide points to and partly enters the pipe of the sewer. This provides a guide for the flexible rod cable on the end of which is a suitable boring tool of the cork screw or auger type. The boring tool and cable is advanced forward in the sewer by hand pressure and by means of a twisting action accomplished by a turning tool inserted in the connector. When the obstruction is reached the boring tool thus takes a "bite" into the material, a portion of which can be removed by pulling or jerking the cable back a short distance. The procedure is followed until the entire obstruction is bored out and removed.

The advantage of such equipment lies in the fact that it can be operated from the street surface, whether the manhole is full of water or empty. Being flexible it is peculiarly fitted for sewers having bends and short turns and for the further reason that it can be operated effectively from manholes which are either deep or shallow.

Maintenance Practice

The following is the organization and practice adopted for maintaining more than 1,900 miles of sewers and drains in Baltimore: For the cleaning of inlets and manholes there is maintained a group of approximately 15 men divided into 5 small groups. Each group is equipped with a truck and assigned to a particular territory. A daily record is kept of their activities with the result that each inlet and manhole throughout the city receives attention at periodic intervals. Approximately twelve to fifteen hundred inlets are thus cleaned per week. A group of 20 men with four trucks is constantly employed in maintaining house connections and small lateral sewers, and a third group of 6 men and truck maintains the larger sized sewers and drains. By this method the City's sewers are kept under continuous maintenance, thereby reducing complaints, and eliminating inconvenience to property owners as much as possible. The Department maintains a complaint Division where complaints are received during office hours and arrangements are made to receive calls and render service until midnight. All complaints received during these hours are immediately transmitted to the various maintenance foremen for prompt attention.

No force is maintained after midnight as the number of complaints does not justify it, although in cases of storms and other emergencies we have an arrangement whereby the foremen and laborers can be communicated with promptly and detailed to the work.

Complaint Handling

When a complaint from a property owner is received that water is backing up through the sanitary fixtures, the complainant is advised to obtain the services of a registered plumber in order to determine whether the chokage is confined to the premises or is beyond the limits of private property. The reason for this is that the City of Baltimore maintains the main line sewers, and such portions of the house connection as are laid in public thoroughfares. By this policy expense to the city of investigating private property complaints is reduced to a minimum. Property owners are charged with the cost of removing chokages from sanitary house connections only, when the nature of the chokages indicates a misuse of the sewer. All main line chokages, and chokages in house connections resulting from tree roots, are cleared at city expense.

SOME SEWERAGE OPERATING KINKS*

By A. M. RAWN[1]

Associate Editor

Sewer cleaning operations on a large trunk sewer system give rise to many notions and ideas regarding best methods. If given the opportunity, an intelligent operation and maintenance crew will probably develop that method which best suits the system upon which they are working. In time they will iron out difficulties incidental to their equipment and eventually may evolve something useful to their brethren elsewhere. In the hope that they have done the latter, the writer presents a few operation and maintenance "kinks" which have been evolved entirely by the field operation forces on the Los Angeles County Sanitation Districts' system. Nothing new is claimed for the ideas and many an operation man may recognize in each, or all, a counterpart of what he daily practices.

*From WATER WORKS AND SEWERAGE, May, 1936.

[1]Assistant Chief Engineer, Los Angeles County Sanitation Districts, Los Angeles.

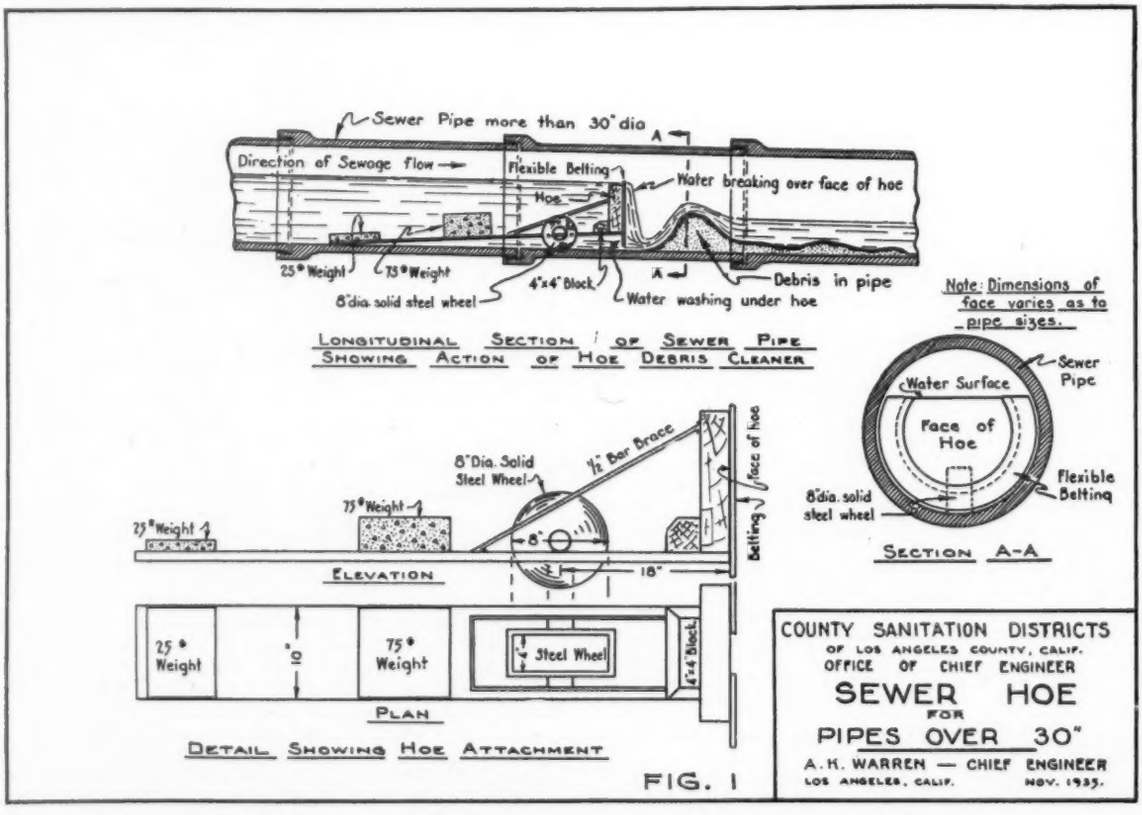


Fig. 1.—The Sewer "Hoe" for Cleaning Sewers Larger Than 30 In. Diameter.

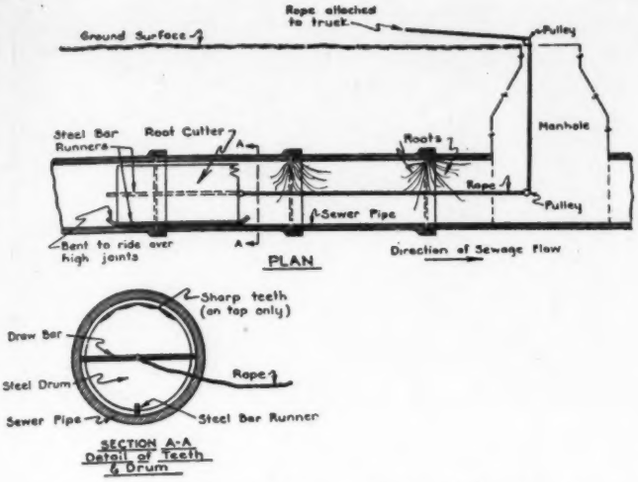


Fig. 2.—Root Cutter for Sewers of 12 to 36 In. Diameter.

Sewer Cleaning

The writer in the October, 1935, issue of WATER WORKS AND SEWERAGE described the use of rubber beach balls for cleaning lines up to 30 inches in diameter. Above 30 inches the balls are expensive and hard to obtain so that for cleaning circular sewers larger than 30 inches in diameter the district forces use a form of "hoe" shown as Fig. 1. It is simply and easily made and can be assembled in the ordinary manhole without much trouble.

In operation the "hoe" is assembled in the manhole and the proper sized flexible belting is attached to its downstream face.

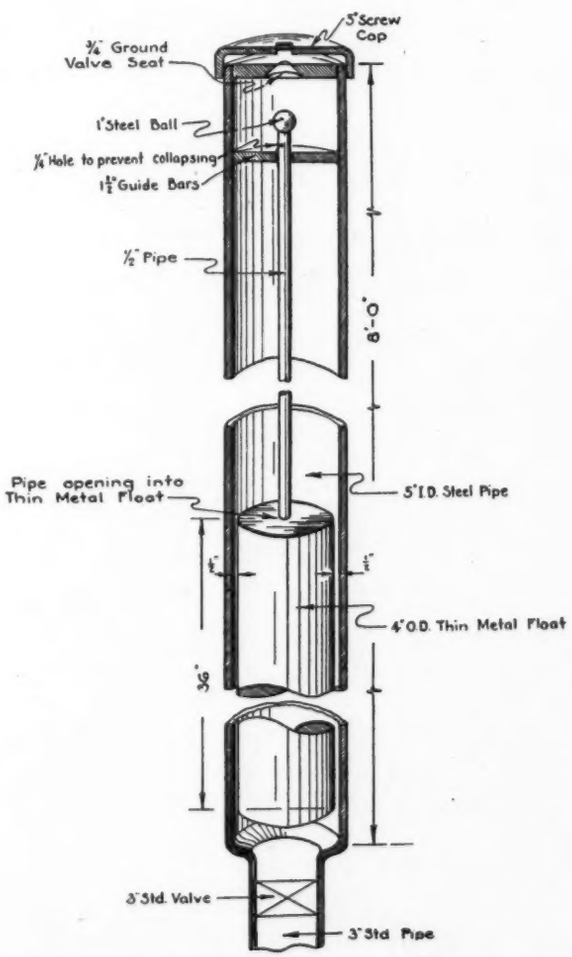


Fig. 3.—Air Relief Valve for Force Main.

Belting is cut and fitted for each size of pipe from 30 inches to 60 inches for circular pipe, and is properly stiffened with sheet metal as is required in the larger sizes. With the exception of the belting attached to the face of the "hoe," the same equipment is used for cleaning all sizes from 30 to 60 inch pipe lines.

Following its assembly in the manhole, the "hoe" is thrust into the downstream pipe and the trail line is attached to the tail board holding the weights. The sewage backing up behind the "hoe" propels it through the pipe, moving any accumulated debris ahead to the manhole below.

The "hoe" is surprisingly efficient in cleaning the sides and invert of the line. Care must be taken to secure a reasonably close fit between the pipe and the outer edges of the belting so that the belting will have to flex forward to permit the escape of water collected behind the "hoe" face. If this precaution is taken, and the tail board is suitably weighted, one may be assured that just about anything movable below the backed-up water line will be shoved or sluiced ahead to the next manhole. Like the pneumatic cleaning ball, described in the October, 1935, issue of WATER WORKS AND SEWERAGE, the "hoe" moves easily over fixed obstructions.

Root Cutting

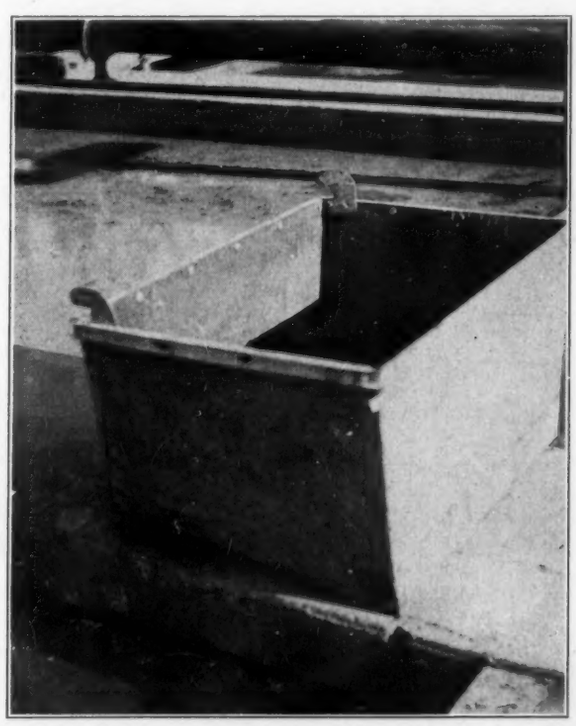
Many types of root cutters have been manufactured and sold. A number have been tried on the districts' lines. None of them, however, has proven much more efficient than the simple, inexpensive device shown herein as Fig. 2. It is simply and easily made of ordinary butt-welded steel pipe of commercial sizes.

To make it, take a piece of pipe about 18 inches long, serrate and sharpen the edges of both ends, and weld four shoes to the outside of the pipe. Affix halters for the pull and trail lines—and the job is done.

For an 8-inch line job use a 6-inch diameter pipe and ¼-inch strap runners or shoes. For a 12-inch line, use 10-inch pipe. A 12-inch diameter pipe is large enough for a 15-inch line, and so on. The sharpened notches in the pipe ends should be rather deep and wide so that they may pinch and hold the root, tearing or cutting it loose at its point of entrance into the line at which point it is usually quite small and relatively weak.

The pull line is thrust or pulled through with sewer rods, if it cannot be floated through the line. Pulley-blocks are then suitably arranged at the downstream manhole so that pulling may be done with the maintenance truck.

Lacking the proper diameter pipe for an operation, the operation and maintenance crew once manufactured a similar root cutter from a discarded water tank salvaged from a dump heap. It is still used upon occasion.



Containers Placed Next to Tank Ready for Skimmings.

Air-Relief Valve

Figure 3 illustrates a type of air relief valve used in the 3½ mile (36-inch diam.) effluent pump line leading from the districts' sewage treatment plant. The valve pictured is installed at a summit in the line about 2,000 feet from the plant where air must be tapped off if the line is to operate efficiently. It is also important that none of the effluent escapes through the blow-off.

A number of valves were tried but all operated with indifferent success until that sketched was installed. As may be seen, it consists of a simple float operating a steel ball valve attached to the end of a section of ½-inch pipe. The ball seats in a ground valve seat tapered to catch and center the ball as it rises. The valve case is constructed from a 5-inch diameter, butt-welded, steel pipe.

The secret of the mechanism is the small hole drilled in the ½-inch pipe near the ball. This is to permit admission of air into the light metal float, equalizing the pressures inside and out on the float and preventing collapse of the thin metal cylinder. When first constructed the hole was omitted and the float promptly collapsed, rendering the valve ineffective. When rebuilt, the air inlet hole was drilled and the valve, operating about three times a minute, has been in continuous service for more than six months.

It may be thought that condensation or spray might eventually fill the float cylinder with water, and the writer admits having shared such a belief at one time. Convinced, however, by the plant chief operator who designed and built the valve, that if the float did eventually fill it could be easily drained and put back into service, the installation was permitted. Now it has been proven that the principle is sound. No water escapes through the valve.

Grease Collection and Incineration

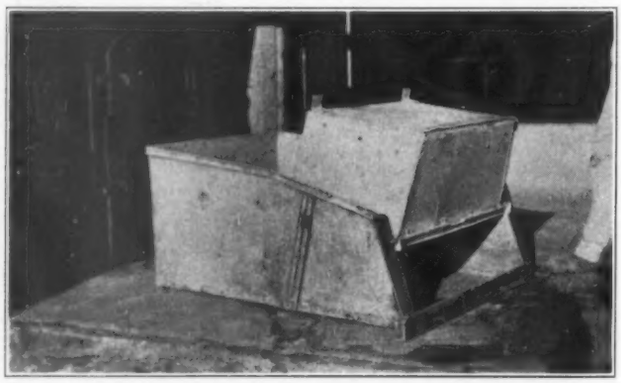
At the district's treatment plant, grease is skimmed manually from the tanks and burned. For a number of years skimmings were accumulated in galvanized iron cans and transported to drainage beds. When drained they were picked up in wheelbarrows and conveyed to the incinerator.

Handling the galvanized iron cans was a dirty and expensive item of labor as was the spreading on drainage beds and the reaccumulation and transportation to the incinerator. The grease draining beds were odorous in spite of all precautions and the incinerator ash was about 90 per cent sand—the latter being picked up with the grease from the beds.

The chief operator requested and received permission to construct the containers and transporting barrow.

The container or pan may be made any convenient size. That shown holds about 3 cubic feet. Placed in the bottom of the pan and standing on a rigid framework which elevates it an inch off the pan bottom, is a ¼-inch square mesh screen, the purpose of which is to provide drainage for the skimmings. The pan is so constructed that all drainage is toward the 1½-inch pipe shown in the right front of the pan at the base. Drainage from the skimmings goes directly back into the sewage tank.

The pan is filled with skimmings as they are taken from the sewage and permitted to drain for a couple of hours before being taken to the incinerator. Twelve such pans are in use at the plant.



Storage Pan at Incinerator.

Wheel Barrow Used for Transporting Skimmings Containers to Incinerator.

For transporting the pans to the incinerator the pneumatic tire wheel-barrow (illustrated) was constructed and is used. The operator wheels up to the high side of the pan, steps across it and engages the forward cross brace in the two forward pan dogs, then upon lifting the wheel-barrow handles, the rod welded across the back of the pan catches in the two swinging hooks attached to the barrow handles, and the load is securely engaged. The penumatic tire prevents wear on concrete walls and cross walks; makes for easy rolling.

It may be seen that when the pan is lifted the slope of the pan bottom is reversed and any water shaken out of the screenings during transportation stays in the pan until it is set down.

At the incinerator a movable sheet metal storage pan is located in front of the charging door. The operator swings the loaded wheel-barrow handles over the storage pan, engages the pan's back rod in the two forward dogs in the storage pan, releases his load and then tips the screenings into the storage pan with a hook.

The operator's hands do not come in contact with the skimmings or the containers at any time and the curse has been eliminated from an operation job that was once a filthy task. Moreover, the work is greatly expedited.

The pans are cleaned daily with hot water and once a week with grease solvent. The pans and the wheelbarrow were all built in the plant shop by the plant operators.

Representative Water Rates

That where water is the dearest it has been made available at such comparative low cost to consumers is a situation stressed in its publicity releases to consumers by Los Angeles' Department of Water and Power.

What the Official Bulletin "Water and Power" has to say to Los Angeles water takers is of interest.

"Water and Power" has the following to say:

"Los Angeles consumers pay the low rate of 13 cents for 100 cu. ft. (750 gallons) of pure water brought in from mountain streams 250 miles distant. For the same amount of water the average charge in 183 of the larger cities in the United States is 18 cents."

The following rates charged by representative cities are cited in comparison:

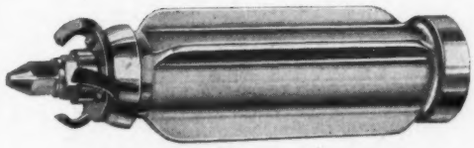
San Francisco	28 cents	Youngstown, O.	20 cents
Pittsburgh, Pa.	25 cents	Miami, Fla.	19 cents
Indianapolis, Ind.	22 cents	Boston, Mass.	15.4 cents
Des Moines, Ia.	22 cents	St. Louis, Mo.	15 cents
Los Angeles	13 cents		

Any municipality which can show a rate below the 18 cents per 100 cu. ft. average in 183 representative American municipalities would do well to utilize the figures quoted, release the "story" to the local press and distribute reprints of this "news" with its water bills.

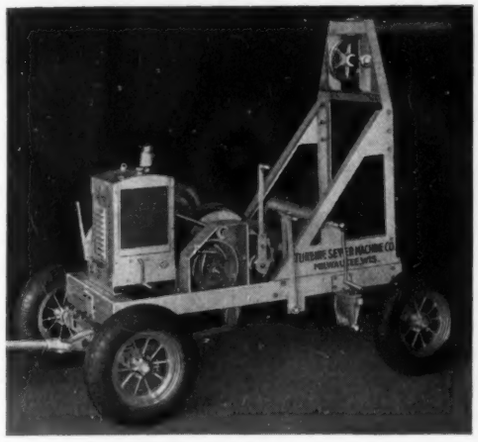
TURBINE SEWER MACHINE CO.

MILWAUKEE • WISCONSIN

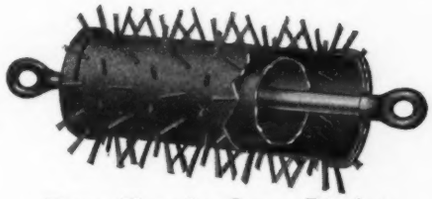
EASTERN DISTRIBUTOR: TURBINE SEWER MACHINE SALES CO.
276 Lafayette St. New York City



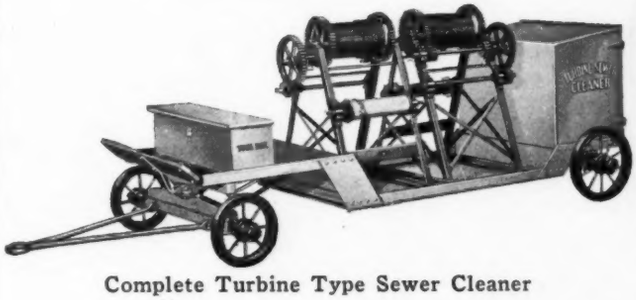
Self-Propelling Ferret Turbine



Power Sewer Cleaner

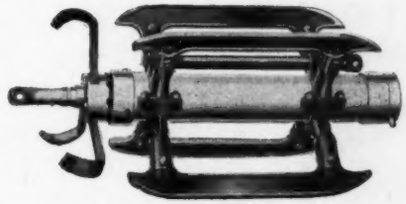


Turco Hercules Sewer Brushes

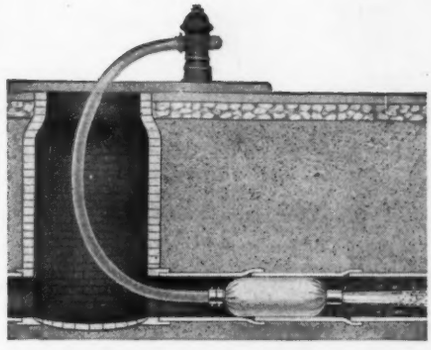


Complete Turbine Type Sewer Cleaner

Sewer Rods



Standard Turbine Adjusted to Clean Twenty-inch Sewer



Turco Sewer Flushing Bags

EVERYTHING IN SEWER CLEANING EQUIPMENT

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SERVICISED PRODUCTS CORP.

6051 WEST 65th STREET — CHICAGO

ASPHALTIC SEWER JOINTING MATERIALS

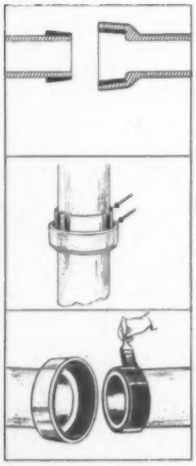
● TWO-IN-ONE DIE-CAST SEWER JOINT ● SEWER PIPE BELT ● SERVITITE ● TUFFLEX ● Q.D. PRIMER ● HOT POURING COMPOUND

TWO-IN-ONE DIE-CAST SEWER JOINT

● Water-tight and root-free joints are assured by the Two-In-One Die-Cast Method. All the work is performed above the ground. Under the Servicised System, the even surfaces of the two cast joints come into close contact and effect a tight joint, making an ideal condition which counteracts root growths, solves the question of centering, is ideal for wet trenches and meets the utmost demands. Under the System it is only necessary to have one die. One pipe is set up on the other and both sections of the complete joint are poured at the same time. All the work is done above the ground, and no stooping over is necessary to pour a joint around the base, as this is done at a uniform level.

● Two-In-One Die is a single die, is furnished and so prepared that the taper of the die takes care of both sealing bands. The die is placed on the bell end of the pipe which is placed up-right and the spigot end of the second pipe rests in the die.

● With the Two-In-One Die-Cast Method of joining pipes, the pipe is always prepared ahead of placing into the trench. The pipe can thus be prepared during any part of the year and in advance of the actual laying, if desired. The Two-In-One Die Method of casting joints costs less than any other method as there is less handling of pipe, less bending over, practically all of the work being done at waist level.



● The Hot Pouring Compound is poured in such a manner as to leave an asphalt band in the bell end of one pipe and a similar band on the spigot end of the other. Before using the die is prepared with a coat of anti-stick preparation so as to avoid any of the asphalt adherring to the die. The upper pipe is then removed and becomes a receptacle for the next set of pipes, the die being removed, cleaned and again lubricated with anti-stick preparation. The spigot now bares an asphalt band and on the bell a similar band which are consistent to each other. Before installing each band is coated with two-in-one solvent which forms the bond assuring an absolute watertight connection.

SERVICISED PREMOULDED SEWER PIPE BELT

The perfect job to be desired in a sewer joint is one which is long-lived, water-tight, flexible, root-proof, and resistent to acids. All these qualifications are met by Servicised Pre-Moulded Sewer Pipe Belt. This belt also provides the important factors; Ease of Installation, Ease of Inspection and Saving of Labor.

THE PRODUCT, NEAT, MODERN, CLEAN

Servicised Pre-Moulded Sewer Pipe Belt, moulded while hot, in the course of manufacture, is belt-shaped and in cross-section is wedge-shaped, conforming to the shape of the bell and giving a wedging action when driven in. The ends of each section of belt are beveled so that when installed tightly there will be no crevice where the ends meet. The belt is calked in to tightly fill the annular space between bell and spigot of sewer pipes. Belts are made for all sizes of pipe according to A.S.T.M. dimensions and special belts are made to order where sewer pipe is not in conformance with A.S.T.M. standards.

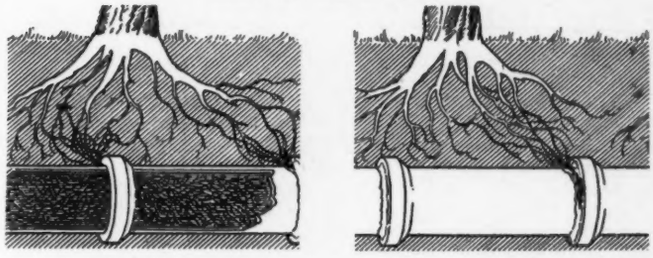
The special composition and properties of Pre-Moulded Belt go together to form a superior product. It is a uniform mixture of selected fibrous asbestos and refined bitumens of special character, such as only Servicised can make due to very wide experience in the fabrication of asphalt specialties.

SERVITITE—COLD PLASTIC COMPOUND

The problem of root-clogged sewer pipes is eliminated by the use of Servitite. Servitite, used cold, does not shrink on hardening. Servitite sets under water. Servitite comes in units of 140 pounds, of which 100 lbs. is in powder form and 40 lbs. in liquid form.

Servitite is manufactured to provide an economical material always on hand for quick use on any sewer jointing job. Servitite is highly adhesive to clay or concrete pipe and hardens shortly after being installed. Servitite is flexible and acid-proof and more than anything—ROOT-PROOF—having incorporated in its composition an ingredient poisonous to vegetation. The special feature of Servitite is its being furnished in two units for mixing on the job as desired Measuring containers are furnished with each order so that the contractor can prepare the desired amount of material to complete the job.

ROOT GROWTH



Inferior Material

No Root Growth with Servitite

TUFFLEX

Cold troweling plastic for sewer pipe joints. Like Servitite, Tufflex is also a plastic cold troweling sewer compound. It is highly adhesive and produces an absolutely watertight connection. Tufflex is mixed at the factory and comes to the job ready for instant use without any additional preparation necessary. It is furnished in convenient size airtight drums. When only a portion of the drum is used the airtight cover is replaced to keep Tufflex in perfect condition for future use.

Sewers require repair when broken due to ground movement or trench settlement. Tufflex, being a highly flexible material, will take up this movement and at the same time assure watertightness due to its high degree of adhesion. This eliminates the possibility of foreign matter, root growths and infiltration of surface water. Tufflex also is made with a root deterrent and, being cohesive as well as adhesive, does not allow infiltration which is usually found in non-flexible sewer compounds.

Tufflex has been widely used for many years and is one of the most important pipe joint compounds on the market today. Cold troweling has many advantages over hot pouring or cement grout joints. Preheating time is saved as well as expense of runners and the additional labor saving for installation.

OTHER PRODUCTS

HOT POURING COMPOUND. Servicised Hot Pouring Compounds are specially prepared by experts to meet the extremely adverse underground conditions. They consist of tough flexible petroleum asphalt with a definite percentage of finely ground, insoluble mineral filler. Thus composed, the material remains uniform and raises the softening point of asphalt to increase flexibility in cold weather and prevent erosion and flow in hot weather. The foregoing components can be tested.

Q.D. ASPHALT PRIMER. Q.D. Asphalt Primer is of particular advantage in laying sewer pipe under adverse conditions. Good joints can always be made up by the use of Servicised quick-drying asphalt primer in conjunction with premoulded belt or any of our other jointing compounds, either of the hot pouring or plastic types. This primer is a bituminous material of brushing consistency which, on exposure to atmosphere, sets up into a tough asphaltic seal. The light solvent in Q.D. Primer evaporates after being subjected to the atmosphere and leaves a tough mastic coating which assures absolute adhesion between the jointing compound or premoulded belt and the sewer pipes.

SERVICISED EXPANSION JOINTS are a necessary protective material for walls, floors, roofs and sizeable monolithic construction generally. To prevent and control cracking; to protect against severe fractures; to prevent excessive pressures which can result only in damage—Servicised Pre-Moulded Expansion Joints are needed. The principal types are Pre-Moulded Asphalt, Cork Rubber and Sponge Rubber Expansion Joints. Servicised Pre-Moulded Expansion Joints play an important part in the preservation of many structures; some of them the larger engineering undertakings of recent years. Among other installations, Servicised furnished the heavy special expansion joints installed in the mammoth sewage disposal plant of the Sanitary District of Chicago.

SEWER FLUSHING*

Good and Indifferent Practices

By JOHN D. WATSON
Consulting Engineer, Ruislip, England

This article reveals much pertinent to "Sewer Flushing" practices and presents what may be considered satisfactory flushing and what will prove a waste of effort and funds. The all important depth of flow in flushing, as compared to velocity flow without the needed depth, is pointedly emphasized. If we interpret correctly, many readers will find it necessary to consider some of our existing pseudo-flushing practices as little more than sewer "rinsing," after reading the depth—velocity discussion by Mr. Watson—an authority with a wealth of experience and years of observation to draw upon.

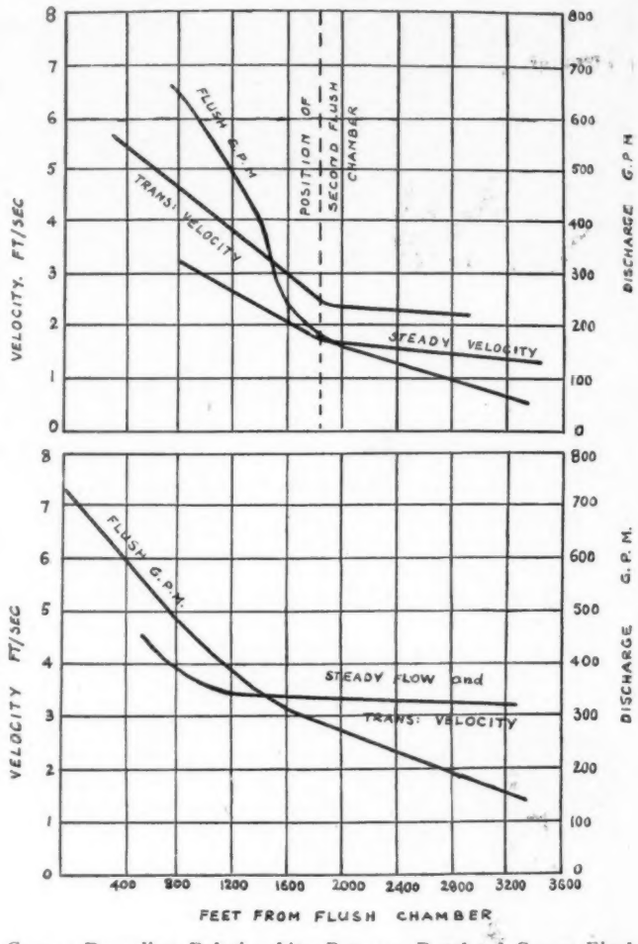
The basic condition upon which calculations for sewer flow should be made is that the sewer have a self-cleaning velocity. In other words, it should never tend to silt up even though the dry weather flow condition persists for long periods while at the same time it must be capable of taking storm water, unless it is wholly diverted from it. Provided they are properly constructed it is not usually difficult to give sewers a sufficient fall for this condition to be fulfilled. Main sewers will work with little or no trouble when laid on a grade of 1:1000 or less and, when the London Main Drainage was designed some 70 years ago, experiments showed that a velocity of 1½ miles per hour was sufficient, and very little cleaning is necessary in these sewers today. They vary from the familiar oval section of 4-ft. x 2-ft. and 8-in. to circular sewers of 12-ft. diameter. They are mainly built of brick.

Trouble is rather more likely to occur in the smaller branch sewers which have to be put in of a size to allow of increasing population so that for perhaps 10 or 20 years, normal flows are insufficient to maintain a self-cleansing velocity; and, while it is usually possible to divert surface water into them, it usually has to be kept out in order to save pumping and purification costs. The system adopted at one time at Hamburg, of constantly flushing the main sewers from a small river, enabled them to be laid at 1:3000, and to be run practically half full continuously, but that principle has rarely been adopted. The usual practice, when artificial flushing is resorted to, being either to provide gates to dam back the flow and then to release the pent up sewage for the purpose; or the use of tanks operated by an automatic syphon, the latter arrangement being as a rule the better one.

The Great Importance of Depth in Flushing

When arranging for it the important points to bear in mind are, that the flush is not going to be effective over any great distance, and that it is the depth of flow over the invert of a sewer which is the most effective in moving the material which is the main cause of obstruction. That of course, is the condition intended to be provided by the oval sewer, silt being usually the main cause of the trouble in the present connection. In the form of road detritus, though it may reach the sewers mainly in times of storm when there should be sufficient velocity to carry it to the outfall, road detritus in the average condition has been found by experiment to require a velocity of nearly 1-ft./sec. to keep it on the move and if small pieces of broken stone and similar material get into the sewer (which by some unaccountable means they do) such, according to size, will require a velocity of 2½ to 3½-ft./sec. to move them. Incidentally, it is such obstructions in the first instance, as a rule, which cause a general obstruction to build up.

Such material always moves along with a speed of travel less than that of the stream (usually not more than half) and though 2½-ft./sec. flow velocity may move a piece of stone it will only barely do so in 1-in. depth of water. But, if the depth be increased to 6-in. it will roll along quite easily at 2-ft./sec., confirming the contention already made that it is the depth of liquid in the sewer that is the really important factor in keeping it clean. Therefore, the conclusion to be reached, is that, in circular sewers at all events and more particularly in the average branch up to 30-in. dia., the basic cause of silting is *insufficient depth* of flow *rather than velocity;* and, especially is this evident in lateral sewers which only receive intermittent discharges from the dwellings connected to them. Thus, deposits commence which ought to be periodically flushed away because if they are not removed, although they might not immediately render the sewer inactive, they cause a filmy growth (slime) to appear on the pipe wall. This growth in turn further reduces the velocity, and so matters go from bad to worse with the additional evil of the sewage becoming septic and producing large volumes of sewer gas, with its well known attendant evils.



Curves Revealing Relationships Between Depth of Sewer Flush (Rate of Flush Discharge) and Effects Down-Sewer

This can be demonstrated in a simple manner by purposely putting some coarse sand or fine gravel in a sewer. Then it will be found that while motion is set up by dragging action, the particles are more or less lifted up into the stream and further motion is carried on by the added effect of suspension. The greater volume of material is naturally carried in the lower layers of the stream, the total quantity being proportional to the depth. Motion, too, will be seen to be from the sides of the sewer towards the centre, the major portion of the suspended matter being carried along the centre of the stream. The amount and the size of the material being carried in suspension

*From WATER WORKS AND SEWERAGE, August, 1937.

depends upon the velocity of the stream and its depth of flow. But, to a much greater extent depth is controlling, because in appreciable depth of liquid the particles are thrown to a greater height; and, as the velocity of descent of the particles is the same in both cases, the deep stream carries the particle further owing to the greater opportunity of remaining suspended.

Effects of Flushing

The conclusions to be reached, therefore, are that as a general rule it is advisable to provide means for flushing pipe sewers when they are laid at flatter gradients than those listed below:

12-in.....1:300	21-in.....1:600
15-in.....1:400	24-in.....1:700
18-in.....1:500	27-in.....1:800
30-in.....1:900	

Between 2,000 and 3,000 gallons at a flush, according to the size of the sewer and provided it is released once or twice every 24 hours, usually suffice. In any event it should be an amount that, when it does come into the sewer, practically fills it at that point. This, because the depth of the flushing wave near its point of origin decreases as it moves downstream to a point at which the depth and velocity are but little affected by the discharge. As an example, one can consider a 12-in. sewer flush by a 1,500-gallon tank through a 10-in. syphon in 1¼ minutes.

On the accompanying chart the upper set of curves relate to such a sewer laid at 1:630. One curve reveals transmission velocity, the other steady-flow velocity. As regards the former, the rate of transmission, at the commencement of the flush and at different distance from the flushing chamber, is that which would give the maximum scouring velocity, assuming the flush to be discharged into an empty sewer. This velocity lasts but a few seconds and its effect reaches but a short distance. In the matter of the steady-flow velocity, during the period when the maximum volume of flushing water is passing at different distances from the flushing chamber, it will be observed that this velocity lasted for a minimum period of 1 min., the period increasing with the distance from the flushing chamber. There is also a third curve which reveals the maximum volume of flushing water in gallons per minute at different distances from the flush chamber. From this curve, the effect of varying the amount of flush water discharged per minute can be determined. The lower set of two curves, in comparison, relates to a 9-in. sewer having a flush of 750 gallons for one minute.

Facts and Conclusions

The principal facts which become apparent from an examination of these curves are that:

(1)—The velocity dies off rapidly at first until it attains a certain value after which the diminution is small. As a result the flush is transmitted over an appreciable distance, probably about one mile.

(2)—With flat gradients, the velocity when the maximum volume of flush water is passing is less than the rate of transmission at the commencement of the flush, the difference gradually decreasing as the gradient decreases until the velocities are identical—such being indicated by the lower graph.

One can conclude, therefore, that the slope of the advancing flush will gradually flatten as the distance from the flushing chamber increases except where the gradient is sufficient to secure a high velocity. It is noticeable, also, how the steady flow velocity is over 3-ft./sec. at a distance of more than 3,400 ft. from the flush chamber. If, therefore, the sewer gradient is reasonably good, though appreciably less than that above set out, a good flush (rapidly discharged) will keep a sewer clean for at least half a mile even though its capacity be considerably in excess of normal dry weather flow requirements. And that, as already indicated, is the main purpose of artificial flushing.

CHAMPION CORPORATION 4714-38 Sheffield Avenue HAMMOND, INDIANA

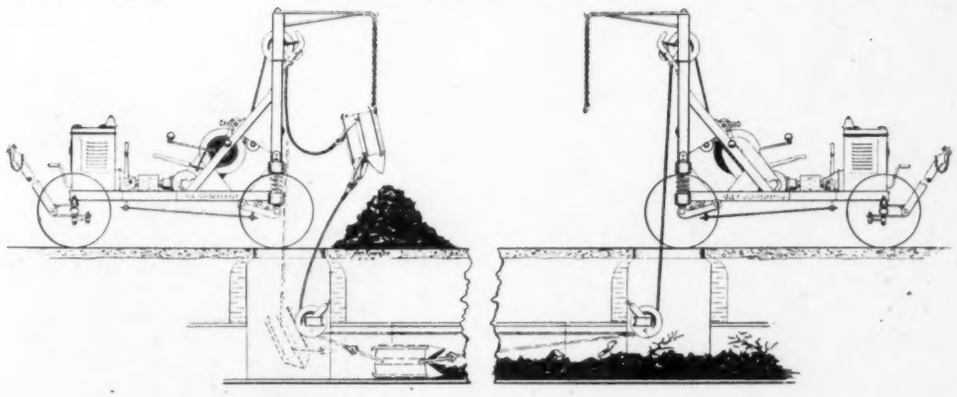
YOU CAN SERVE YOUR CITY with ECONOMY IN ITS EXACT INTERPRETATION by the O K CHAMPION METHOD OF SEWER CLEANING

Models and Prices Fit ANY

Village — **O K CHAMPION Junior Sewer Cleaner**

Town — **O K CHAMPION Standard Sewer Cleaner**

City — **O K CHAMPION Power Sewer Cleaner**



A Wide Variety of Accessories Included With Each Model from a complete line of debris-removing tools

O K CHAMPION patented expansion buckets, manhole guide jacks, easy coupling floating sewer rods, root removers, gouges, collapsible scrapers and water motors.

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68th and Upland Streets, Philadelphia

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CHARLOTTE, N. C., T. C. Heyward, Independence Building.

KANSAS CITY, MO., J. J. Heinrickson, 4706 Broadway.

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CANADA, Simplex Valve & Meter Company of Canada, Ltd., S. A. McWilliams, 60 Front Street, West, Toronto, Ont., Canada.

CUBA, Daniel, Inc., Metropolitan Building 814, Habana.

HAWAII, W. A. Ramsay, Ltd., Fort and Queen Sts., Honolulu.

MEXICO, F. A. Zapata, Apartado Postal No. 99, Mexico, D. F., Mexico.

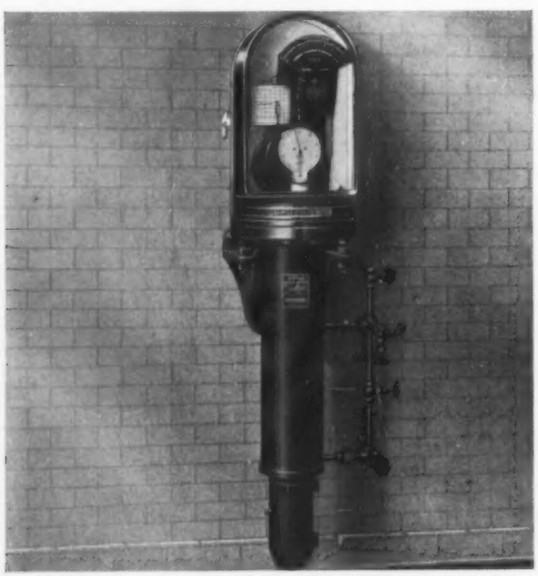
PUERTO RICO, Roberto Colon Machinery Manufacturing Co., Comercio Street 17-19, San Juan.

PRODUCTS:

Simplex Venturi Type Meters for Measurement of Water, Sewage, Sewage-Sludge, and Air; Filter Rate of Flow Controllers; Loss of Head and Rate of Flo Gauges; Simplex Pump Casing Tap Meters; Pilot Tubes and Manometers; Portable Pitot Recorders; Water Level Gauges; Air Release and Air and Vacuum Valves; Proportional Chemical Feeding Devices; Sewage Aerators; Rotary Distributors; Hydraulic Equipment of Special Design; Sand Expansion Indicators, Summators, Air Differential Meters, Simplex Gyrometers.

SIMPLEX METER REGISTERS:

Primarily designed for use with Venturi tubes, Simplex meter registers are also used with Simplex pitot rods, orifice plates, and pump casing taps, as primary actuating devices. They are designed for use in measuring liquors and gases under all pressure conditions and are particularly fitted for the measurement of raw water, wash water, filtered water, raw sewage, screened sewage, mixed liquor, raw sludge, digested sludge, and air.



Noted for their ability to operate under small Venturi heads, Simplex meter registers measure accurately flows corresponding to water differentials of from ⅛" and up. Particularly designed to measure accurately the slightest change in rate of discharge, Simplex meters can be furnished to either indicate, record, or totalize the flow, or in any combination of these functions. Simplex meter registers of standard form are also furnished for the measurement of discharge through egg-shaped flumes, Parschall Venturi flumes, weirs, and other forms of primary devices wherein a free-falling discharge is present as well as for use with Simplex Pump Casing Taps.

Simplex meter registers can be arranged for mechanical totalization of the flow from any number of individual instruments whereby the total flow can be transmitted to either a large dial indicator, a total flow recorder, or a complete summation meter of the indicating, recording, and totalizing type.

Simplex meter registers can be operated by air differentials, thereby preventing the entrance of any sewage, sludge, or corrosive liquors into the meter float cylinder.

Each instrument has included with it as a standard item of equipment a device whereby its accuracy and sensitivity can be checked at any time during its period of service. Newly developed meters include the Simplex Impact Flume and Meter which enables accurate measurement of free discharging fluids by transforming the energy gradient into terms of rate of flow.

The Simplex Gyrometer is a differential pressure operated totalizing instrument designed for wall or panel mounting and adapted to the measurement of both liquids and gases.

SIMPLEX FILTER RATE OF FLOW CONTROLLERS:

Provide an efficient device for the operation of gravity or pressure filters which maintain the rate of discharge through the bed at a constant, regardless of variations in pressure or water level,

utilizing as an operating means only the pressure effect of the water flowing through the filter effluent line.

Simplex Controllers operate with the lowest obtainable head losses when wide open; attain the highest degree of accuracy in control without the use of compensating mechanisms; and are capable of covering the largest possible ratio from maximum to minimum rates with any given size of unit; avoid the use of any electrical mechanisms in their operation; start quickly from a wide open position, and take the rate for which set in less than fifteen seconds.

The Simplex, direct-acting controller is arranged for either straight-through, right, or left-hand outlet as may be desired, and can be installed in either a vertical or horizontal line, as required.

Simplex rate of flow controllers can be equipped with the Simplex master control system, whereby the rate through the entire battery of filter units can be changed from a single point on the operating floor or wherein the rate through each controller unit will vary with the elevation of water on the filter or in the clearwell.

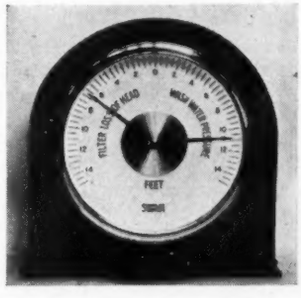
Simplex rate controllers can also be arranged with means for changing the rate from the operating floor.

SIMPLEX FILTER GAUGES:

These may be furnished in any combinations of indicating, recording, and totalizing rate of flow with indicating and recording of lost head, wash water rate or sand expansion.

Simplex gauges are of the mercury float operated type, wherein the Simplex bell-shaped float is used to provide uniform graduations of flow on both indicating dial and recording chart.

Similar in design to the Simplex meter register, Simplex filter gauges respond to the slightest variations in rate or loss, and will measure accurately over the entire range with an average error not exceeding ± 3%.



Simplex rate of flow gauges have been arranged for totalization, wherein there is shown on a single 24" diameter dial gauge, located on the operating floor, the total flow through any or all of the controller units. There can be mechanically linked to the total flow indicator, chemical feeders or chlorinators, thereby providing accurate control of the chemical dosage at all time during the plant run.

Simplex Sand Expansion Indicators and Recorders provide a means whereby filter efficiency can be increased and wash water costs reduced. They are available for installation on existing filter units as well as on new plants.

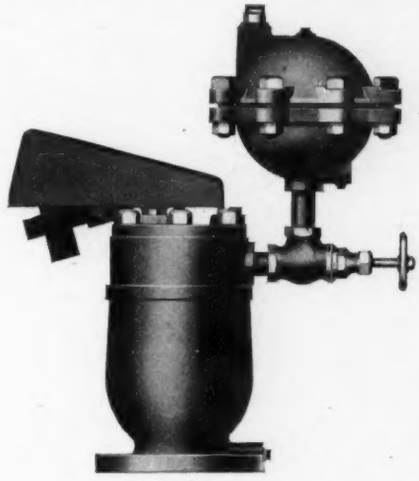
Also available for measuring the depth of water in clear wells, wash water tanks, sedimentation basins, are Simplex water float operated gauges, which can also be furnished in any combination of the indicating and recording types.

Simplex gauges are accurate, dependable, and easily intsalled—a high-grade quality product, made with precision and care.

SIMPLEX AIR RELEASE AND AIR AND VACUUM VALVES:

In the design and operation of large steel pipe lines flowing under gravity, consideration should be given to the possibility of collapse, in case, for any reason, the internal pressure is reduced below that of atmosphere.

Simplex Air and Vacuum Valves are used on large mains, where there is danger of collapse, due to vacuum; the valve breaking the vacuum, thus preventing collapse. They facilitate the filling of the main, since wide open until full of water.



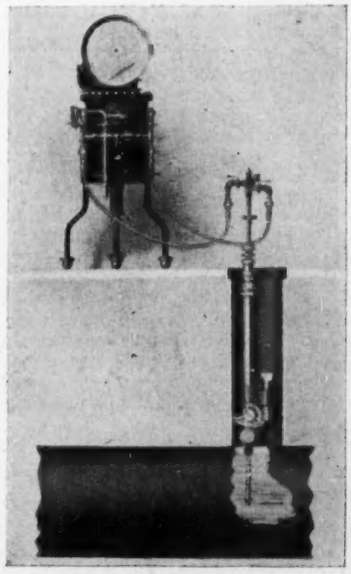
Simplex Automatic Air Release Valves have been designed to release, automatically, accumulations of air. They possess the merits of continuous operation without attention; simplicity; compactness; accessibility, and low cost, all of which are proved by over fifteen years' satisfaction to many users. Located on the high portions of the line, they insure automatic venting of the line and a continuous flow.

SIMPLEX TUBE RECORDERS:

For use with Simplex Round or Flat Pitot Rods —afford not only a record of velocity but can be furnished with pressure elements to give simultaneous readings of velocity and pressure.

This equipment may also be used for Water Waste Surveys or for conducting water flow investigations.

Indispensable to water works engineers for determining character of the flow in the mains of the distribution system.



METERING MODERN SEWAGE WORKS*

By ROBERT T. REGESTER

Whitman, Requardt and Smith, Engineers, Baltimore, Md.

Flow measurement furnishes an essential part of a treatment process.

In general, the extent to which Venturi metering equipment is provided in sewage works increases with both the capacity of the plant and the completeness, or degree, of treatment to be accomplished.

In many large American cities, where sewage works have been constructed and enlarged within the past ten years, local conditions have warranted the highest degree of treatment. Accordingly, works of the activated sludge type were built.

"Complete" Metering

There is a decided trend toward "complete" metering—especially for works of the activated sludge type. This type of works, providing complete treatment together with the pumping of raw sewage, offers the most numerous applications for metering equipment. The trend is justified from the standpoints of both proper process functioning and operating economy. This tendency is reflected in several more recent designs where provision is made for the parallel operation of similar tanks under different flow conditions. The best combination of variable relationships thereby can be determined. Of course, operation in this manner is intended to be periodic, as the occasion demands, rather than regular. By such means, unfavorable influences can be observed and closer control effected. The works can serve the role of a full-scale pilot plant. In very large works, batteries of similar tanks can take the place of individual tanks so arranged.

Activated sludge works are extensively mechanized and electrified. They present a somewhat complicated arrangement because of the multiplicity of treatment units and process steps. The diagrammatic arrangement here shown serves to illustrate the application of metering equipment for both measurement and regulation of flows to the principal units. This typical layout assumes groups of four units arranged for maximum flexibility and control.

Measurement of Raw Sewage

It is often necessary for raw sewage to be pumped from the outfall sewer to such elevation as will produce gravity flow through the entire plant. Individual centrifugal pumps are metered so that periodical checks can be made on the efficiencies of the respective units. These meters may be equipped with only portable manometers, calibrated directly in rate-of-flow units. On the other hand, individual indicating-recording instruments would show at a glance the immediate performance and would also provide a record of past performance for each pump. This latter scheme is not uncommon in pumping station design.

It is most desirable to provide means for readily ascertaining the total sewage flow to the works. This can be accomplished either by summation (electrically and continuously) of the rates of flow through the individual pump meters, or by providing a separate master sewage meter. In the case of divided flow after pumping, to suit an immediate or future duplicate arrangement of plant, a separate master meter should be provided to serve each half of the layout.

In a large plant it is convenient to have an indication of the total sewage rate of flow at several strategic locations other than at the sewage pumping station. Electrically-operated transmitters and indicators are now used to repeat the summation or master meter readings to such remote points.

Primary Settling Tank Control

It is desirable to have individual settling tanks perform equal duty. As a means of equalizing flows to the units of a battery of these tanks, individual meters with regulating valves can be advantageously used. The valve can be of one of several types, either hydraulically or electrically operated, inserted in the recovery tube of the meter for each tank. This permits the use of a smaller size valve. To minimize the effect upon meter accuracy, the valve should be placed at least two throat-diameters downstream from the throat pressure chamber. The indicating instruments and valve controls can be arranged, for operating convenience, on a control table or panel.

Aeration Tank Control

In the aeration tanks, a properly-proportioned mixture of settled sewage and return sludge from the final settling tanks is agitated and maintained in an aerobic condition by the introduction of compressed air.

The settled sewage, return sludge and air can be metered independently just prior to entering each aeration tank. The sewage and return sludge then mixes upon entering the tank. The air is distributed lengthwise of the tank through porous diffusers arranged along one wall so as to produce a spiral flow of the mixture. When all three meters are arranged at the inlet end of each tank, they can be grouped within the gallery which is usually provided, for the various pipes and feeding channels, along the full width of a battery of aeration tanks.

With an arrangement of independent meters, each meter can be equipped with a regulating valve, as previously described, to permit individual control. For the return sludge, a Venturi rate-of-flow controller may be used, instead of a meter with regulating valve, for each tank. In either case, an automatic control to maintain a predetermined rate can be provided.

A five-dial ratio gauge for the three meters of an aeration tank has been developed. This gauge will indicate, or indicate and record, the rates of flow of air, sewage and return sludge using the first, third and fifth dials, respectively. The second dial will give the ratio of air to sewage, calibrated in cubic feet per gallon. The fourth dial will give the ratio of return sludge to sewage, calibrated in percentage of the sewage flow. The gauges are mounted on control tables which also contain the controls for the respective regulating valves.

Final Settling Tank Control

Final settling tanks remove the floc from the mixture which leaves the aeration tanks. The clarified supernatant liquor passes off as the final treated effluent, to be discharged into the receiving body of water. Meters with regulating valves may be used to equalize the flow of these tanks in the same manner as described for the primary settling tanks. This may only be desirable in the case of numerous units where perhaps one unit is likely to be out of service frequently. Otherwise, the effluent from each aeration tank can flow directly to a corresponding final tank by suitably arranging either stop planks or sluice gates. If these meters are included, they can be grouped with the aeration tank meters in the same gallery, provided that the aeration tanks are of a two- or four-pass type.

For the withdrawal of activated sludge from each final tank, an automatically controlled regulating valve with meter, or a rate controller, is very desirable. There are several other devices, such as adjustable overflow pipes and air lifts, which are also used for controlling the rate of sludge withdrawal. Here again, indicating and recording instruments, controls and push button stations for various motor-driven equipment can be grouped on suitable control tables or panels.

Measurement of Air

In the blower house, each centrifugal blower is provided with a Venturi meter on the intake to measure the flow of free air. These meters are essential for the efficient operation of the blowers and should be provided with individual indicating-recording instruments.

As in the case of the total sewage flow, it is also desirable to provide means for readily ascertaining the total compressed air flow from the blower house, and for repeating this reading in terms of free air to other locations. The previous remarks relating to the master sewage meter apply equally well to a master air meter.

Measurement of Sludge

The measurement of sludge has been a problem in sewage works because of the nature of the material and the relatively small flows encountered. The Kennison nozzle meter is now being used for this service. The nozzle is of special free-blowing design, utilizing the depth produced by a shaped outlet as the rate-of-flow function. The nozzle is equipped with an indicating-recording instrument. These nozzles can be used for measuring the raw sludge and the excess activated sludge prior to digestion.

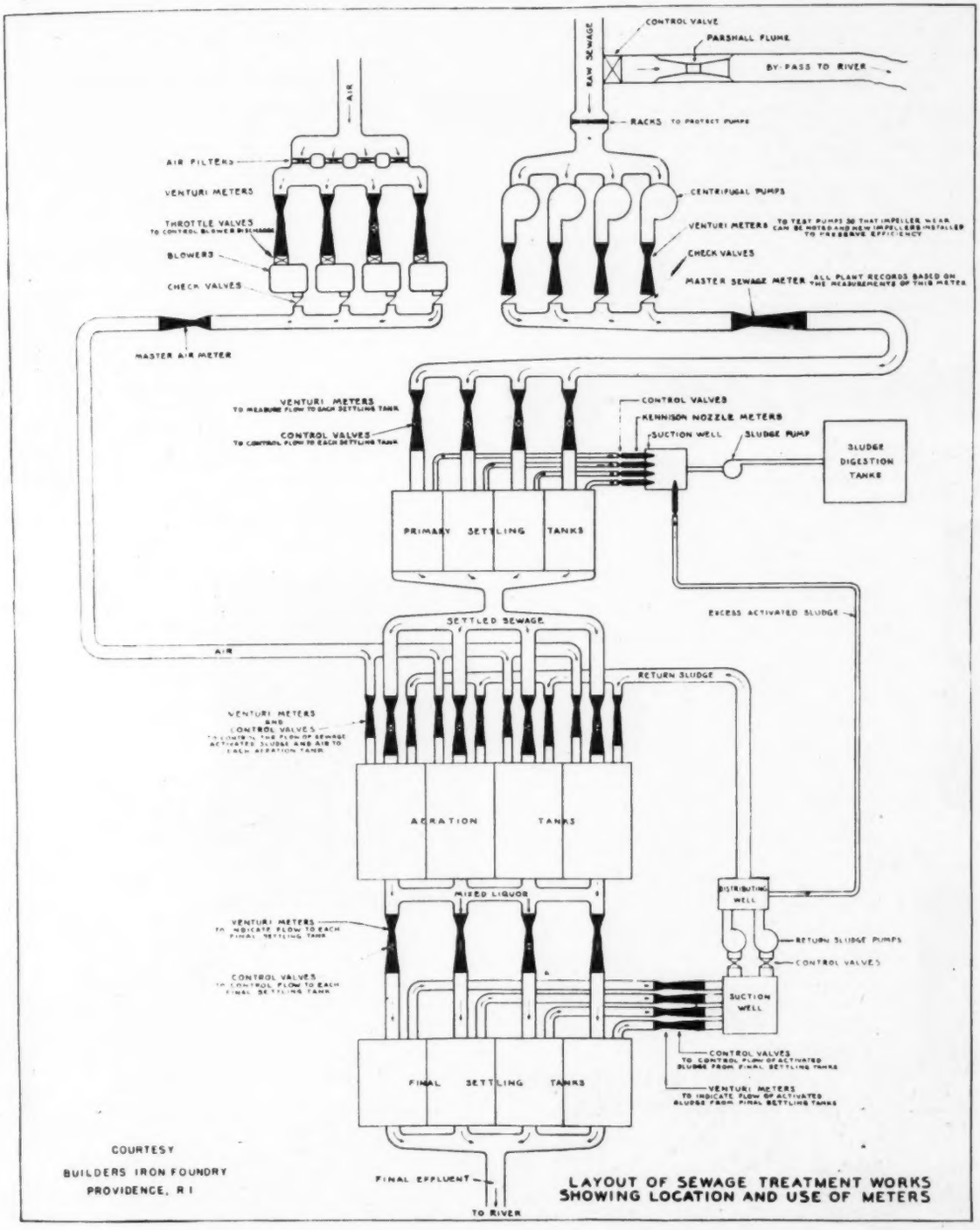
In Conclusion

The cost of providing "complete" metering does not become a major item in the overall cost of sewage works designed for complete treatment. This cost, excluding regulating valves and special control devices, will approximate 3 to 5 per cent of the total cost.

In addition to the applications of Venturi metering equipment already discussed, there are many other special uses for related devices in modern sewage works, especially for control and regu-

*From Water Works and Sewerage—October, 1938.

lating purposes. These include automatic pump controllers, sampling devices, by-pass regulators, constant liquid level controllers and the like. Many such applications comprise combinations of proven mechanical and electric elements backed by the experience and integrity of reputable manufacturers. However, it is the designing engineer's province to originate and supply these combinations for specific problems. Following in the path of industrial advances in the art of automatic control, sanitary works, too, are being so equipped. Most of the features described herein were embodied in the designs for the Columbus and Baltimore activated sludge works, with both of which the writer has been or is now associated.


CONTROL VALVE
PARSHALL FLUME
RAW SEWAGE
BY-PASS TO RIVER
RACKS TO PROTECT PUMPS
AIR
AIR FILTERS
VENTURI METERS
THROTTLE VALVES TO CONTROL BLOWER DISCHARGE
BLOWERS
CHECK VALVES
CENTRIFUGAL PUMPS
VENTURI METERS TO TEST PUMPS SO THAT IMPELLER WEAR CAN BE NOTED AND NEW IMPELLERS INSTALLED TO PRESERVE EFFICIENCY
CHECK VALVES
MASTER SEWAGE METER ALL PLANT RECORDS BASED ON THE MEASUREMENTS OF THIS METER
MASTER AIR METER
VENTURI METERS TO MEASURE FLOW TO EACH SETTLING TANK
CONTROL VALVES TO CONTROL FLOW TO EACH SETTLING TANK
CONTROL VALVES
KENNISON NOZZLE METERS
SUCTION WELL
SLUDGE PUMP
SLUDGE DIGESTION TANKS
PRIMARY SETTLING TANKS
SETTLED SEWAGE
EXCESS ACTIVATED SLUDGE
AIR
RETURN SLUDGE
VENTURI METERS AND CONTROL VALVES TO CONTROL THE FLOW OF SEWAGE ACTIVATED SLUDGE AND AIR TO EACH AERATION TANK
AERATION TANKS
MIXED LIQUOR
DISTRIBUTING WELL
VENTURI METERS TO INDICATE FLOW TO EACH FINAL SETTLING TANK
RETURN SLUDGE PUMPS
CONTROL VALVES
CONTROL VALVES TO CONTROL FLOW TO EACH FINAL SETTLING TANK
SUCTION WELL
CONTROL VALVES TO CONTROL FLOW OF ACTIVATED SLUDGE FROM FINAL SETTLING TANKS
VENTURI METERS TO INDICATE FLOW OF ACTIVATED SLUDGE FROM FINAL SETTLING TANKS
FINAL SETTLING TANKS
COURTESY
BUILDERS IRON FOUNDRY
PROVIDENCE, R I
FINAL EFFLUENT
TO RIVER
LAYOUT OF SEWAGE TREATMENT WORKS SHOWING LOCATION AND USE OF METERS

Layout of an Activated Sludge Plant Showing Location and Functions of Meters.

BUILDERS IRON FOUNDRY

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New York: 20 Vesey St. Philadelphia: Tax Service Bldg. Chicago: 866 Peoples Gas Bldg. Pittsburgh: 1403 Oliver Bldg.

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PRODUCTS

Venturi Meters for Water, Sewage, Sludge, and Air; Orifice Meters for relatively less important lines; Venturi Rate of Flow Controllers; Loss of Head and Rate of Flow Gauges; Reservoir and Tank Elevation Gauges; Sewage, Sludge, and Air Flow and Ratio Gauges. Chronoflo Meters for Distant Metering, Summation of Meter Totals, Continuous Sludge Weighing, Chemical Feeding, Suction Well Level and Pump Control. % Proportioneers% Devices for Water and Sewage Treating and Chemical Feeding.

VENTURI METERS—for Water Works and Sewage Plants

Fig. 1. The Venturi Tube

The Venturi Meter is recognized as the standard means of measuring the flow of water in large mains. It consists of the Venturi Tube (illustrated), installed as a section of the main, and the Register-Indicator-Recorder connected to the Tube by two small pressure pipes. For the measurement of liquids containing large amounts of solids, such as sewage or sludge, the *Air Relay Transmitter* is used to prevent the liquid measured from coming into contact with the Instrument.

Fig. 2. Type M Register-Indicator-Recorder (Model D)

Several different types of indicating and recording instruments are available for use with the Venturi Tube. The *Barometric Type Mercury Manometer*, with a flow rate scale graduated directly in flow units indicates rate of flow. The *Flo-Watch*, Fig. 3, for use on main lines in small plants and secondary lines in large plants, records, indicates, and totalizes the flow. The most popular instrument is the *Type M Register-Indicator-Recorder, Fig. 2.*

This Register has the advantage of unusual ruggedness and extreme accuracy. The Type M furnishes three distinct kinds of information; an indication of the monetary flow through the Venturi Tube; a permanent record of this rate upon a large circular chart; the total quantity on a circular counter dial. Each Type M is graduated for the particular Venturi Tube with which it is to be used.

Fig. 3. Flo-Watch Register-Indicator-Recorder

VENTURI RATE OF FLOW CONTROLLER

Fig. 4. Direct-Acting Controller

Efficient filtration requires a constant rate of flow through the filter bed. This is automatically accomplished by the Venturi Rate of Flow Controller, installed in the effluent line, which gradually opens as the sand friction builds up and the effluent rate tends to drop. The Venturi Tube Controller, providing the highly desirable combination of accurate control and small loss of head, is "standard equipment."

BUILDERS WATER WORKS GAUGES

Fig. 5. Indicator and Recording Gauge

Loss of Head (through filter) and Rate of Flow (Filter Effluent) Gauges are usually mounted on each filter operating table. Indicating and Recording Water Level Gauges are also furnished.

CHRONOFLO METERS AND THEIR USES

Distant Flow Metering

Chronoflo Meters have found a broad application in bringing to a central operating point, from widely scattered locations, accurate records of flow, level, pressure, temperature, gate position, and weight. Chronoflo Transmitters are electrically connected by a simple two-wire circuit to Chronoflo Indicatng and Recordng Instruments. (Fg. 6).

Fig. 6. Chronoflo Register-Recorder

Reservoir and Tank Elevation Gauges

in the pumping station and the water works office downtown, continuously indicate and record level in outlying reservoirs, tanks, or standpipes; eliminate the necessity of taking such measurements manually; and promote efficient pumping.

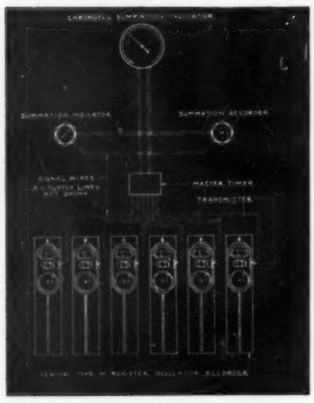


Fig. 7. Totalising Readings of Six Venturi Meters

Distant Transmission and Summation

The Chronoflo Meter is peculiarly suitable for adding the totals of various individual meters installed in widely separated locations. (Fig. 7).

Continuous Sludge Weighing

In many sewage plants one measure of efficiency of operation is the weight of filter cake carried from rotary filters to final disposal. A recent development is the attachment of a special Chronoflo Weight Transmitter to a Toledo Automatic Scale (Fig. 8), which integrates on a counter the total pounds and records on a continuous chart the rate in pounds per hour.

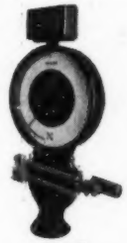


Fig. 8. Chronoflo Transmitter on Scale

Raw Sewage Suction Well Lavel and Pump Control

Builders Iron Foundry Engineers are in a position to work with sewage plant designers in providing Venturi and Chronoflo control devices for this service.

ENGINEERING SERVICE

Inquiries for recommendations covering the adaptation of standard metering and controlling devices are invited. Printed bulletins, illustrating and describing devices mentioned briefly in these pages, are available upon request.

SEWAGE AND SLUDGE PUMPING

By HENRY RYON, Senior Engineer
State Department of Public Works, Albany, N. Y.

Part I—Sewage Pumping[1]

During the past several years a very marked improvement has been made in the methods of pumping sewage and sewage sludge, and special pumps have been developed for this service. Only a few years ago, however, practically all sewage was lifted with pumps designed primarily for handling water.

The centrifugal dredging pump driven either by a steam engine or an electric motor was used with a fair degree of success at many stations. While this pump would handle sand and gravel satisfactorily, rags would wrap themselves around the impeller and necessitate frequent cleaning of the pump either through hand holes in the volute or by the removal of the side of the case. It was not very efficient and the head was limited. The smaller and higher speed centrifugal pump, used successfully for pumping water, gave more trouble, due to clogging, when used for pumping sewage, than the dredging pump.

Reciprocating pumps were used in many cases. These pumps clogged about as easily as the centrifugal pumps; and, if there were any sand or grit in the sewage, gave trouble due to the scoring of cylinders. At one or two large stations the crank and fly wheel pump was used and operated satisfactorily principally because of its large size. The ordinary duplex steam pump served in a few cases. The single acting triplex pump, equipped with ball valves, although not entirely free from clogging, proved to be the most satisfactory of the reciprocating pumps and was used, and is still being used, successfully for pumping both sewage and sludge. Its cost is, however, greater than that of a centrifugal pump and it is rather noisy. It is worth noting that the design of the most modern reciprocating sludge pumps have apparently been copied from the old single acting triplex pump.

At almost all of the old pumping stations the sewage was passed through bar or mesh screens to remove the rags and other solids from it before it reached the pumps. The cleaning of the screens always proved a laborious and unpleasant task, and did not entirely do away with the necessity of cleaning the pumps.

The Pneumatic Ejector

In order to eliminate the trouble of cleaning screens and pumps, the pneumatic or compressed air ejector was developed. This device, which was first used about fifty years ago, operates by allowing the sewage to flow into an iron or steel chamber and, when the chamber is full, automatically admits compressed air above the sewage thus forcing it out through the discharge line. The mechanism operates very successfully, and stories are told of ejectors having been lost for several years and when rediscovered were found to be operating satisfactorily. It requires, however, air compressors, air tanks, and other appurtenances which make the first cost and also the maintenance expensive. In addition to this, the efficiency is very low. The overall or wire to water efficiency when the compressors are operated by electricity vary generally from 10 to 20 per cent. At present, due to the improvements in the design of centrifugal pumps, ejectors are being used less and less except in the very small stations or for sludge and screenings handling.

Pump Impellers

The improvement in the centrifugal sewage pumps has been largely in the design of the impellers or runners. There are, in general, two types of pump impellers, the open and the closed. The open impeller gives larger water ways with the same size casing, but solids clog between the impeller and the casing and rags wrap around the impeller blades. Increasing the clearances to reduce clogging, of course, reduces the efficiency and does not prevent rags from stopping the flow. Open impellers, generally with only two blades, serve well in small sump pumps and also in sewage pumps of small capacities where a closed impeller small enough to give the desired capacity would not pass solids of any size. In most cases, however, the closed or semi-enclosed impeller is to be preferred.

In the design of closed impellers for handling sewage, the water passages have been made wider than in water pumps, all sharp edges and turns have been carefully avoided, thus reducing the chance of clogging to a minimum. As a general rule pumps with impellers of this type will pass solids having diameters about one pipe size smaller than the size of the pump. One manufacturer is producing a pump with a worm feed to force the solids to the impeller of the pump and also cut and crush them against hard steel bars running longitudinally of the screw case. Pumps of this type are giving satisfactory service in several western stations. A rather unique impeller is used in some English pumps. The impeller is open on the suction side and the blades are considerably wider at the shaft than at their ends. The edges of the blades pass very close to bars set on the inside of the case and macerate the solids entering the pump.

It is customary to require the impellers of the pumps to be made of bronze but with ordinary sewage there seems to be no advantage in the use of bronze as compared with that of cast iron. A few pumps have been installed having cast iron impellers coated with enamel and they are said to be giving satisfactory results. The manufacturers claim a slightly higher efficiency for this impeller than can be obtained with the bare metal impeller.

Submerged Vertical Pumps

For the smaller installations probably the submerged vertical centrifugal pump is the most commonly used. The sump may be made of cast iron or steel or may be of concrete. The motor and pump are both supported on a removable iron cover so that the pump can be lifted out of the sump for cleaning and repairs. Enough head room must, of course, be provided to allow the suction to clear the top of the sump when the pump is lifted out. It is also desirable that the discharge be brought up through the same plate so that it may be easily disconnected. In unheated pump houses, however, it is sometimes impossible to do this without danger of the sewage in the discharge line freezing. Where short separate discharges can be used, freezing can be avoided by omitting the check valves and allowing the sewage in the discharge pipe to flow back into the sump after each discharge. If screens are to be omitted it is usually advisable to provide a pump not smaller than 3 inches in size. Such a pump will have a capacity of from 50 to 300 gallons per minute, depending upon design of the impeller and the speed of the motor.

Float Controls

Sewage pumps are usually automatic in operation and the arrangement of the float control deserves more attention than it generally receives. The float may be connected to the electric switch either by a push rod or by a chain running over pulleys with a counterweight to balance the float. Either method operates satisfactorily if properly arranged. Floats that hang unprotected in the sump are apt to be moved sideways by the motion of the sewage causing the chain or rod to bind, or the rod to bend, making the float inoperative. In some designs the rod has a guide at the bottom to prevent such motion, but if the rod sticks in the guide or leaves the guide its inaccessible location makes it very difficult to repair. The lever float, sometimes used, has generally proved very unsatisfactory for sewage because rags are apt to collect on the lever and prevent its operation. As in the case just mentioned it is generally very difficult to reach such a float to repair or adjust it. The best design is one in which the float is arranged in a tube to guide and protect it and a removable cover plate provided over the tube so that the float can be readily lifted out.

[1]From a paper presented before the N. Y. State Sewage Works Ass'n.

Pumps in Separate Dry Wells

For the larger pump stations, and even in the small stations when the conditions will permit, the installation of the pumps in a separate dry well makes the most satisfactory arrangement. This leaves the pumps and their appurtenances accessible for repairs and adjustment. The pumps may be either vertical or horizontal. The vertical pumps have the advantage of requiring a smaller pit and of keeping all electrical equipment above ground and free from danger of flooding, while on the other hand the horizontal pumps are easier to keep in adjustment and alignment. If the pit is deep, one or more guide bearings will probably be required on the shafts of vertical pumps as it is necessary to divide the shafts into lengths of not more than 8 or 10 feet to prevent vibration. I-beams are usually set across the pit to carry these bearings, but it is often difficult to set these beams so as to get a perfect alignment of the shaft. In order to avoid this difficulty, several manufacturers are building steel lattice frames extending from the motor to the pump. The pump and motor can then be aligned at the factory with very satisfactory results. In some cases the motor, shaft and pump have been attached to a heavy channel, aligned at the factory, and shipped as a unit.

With the pumps in a separate dry well it will usually be necessary to provide some means for removing seepage from the well. This may be done with a separate automatic sump pump, or, if a cheaper installation is desired, a small valved connection may be made from the suction of one of the main pumps to a sump and the sump emptied at intervals by closing the main suction valve and opening the connection to the sump.

Design of Suction Well

The shape of the bottom of the suction or wet well is of considerable importance. If it is left flat, solids will collect in the bottom and ferment giving rise to unsatisfactory conditions. The floor of the wet well should have a steep slope toward the pump suctions.

In some cases where the sewage is warm and contains considerable grease, trouble has been experienced due to the grease congealing on the walls of the well and then breaking loose in large pieces and entering the pumps and clogging them. The openings in the impellers of 4-inch horizontal sewage pumps have been stopped several times by this cause.

Bearings and Glands

There does not appear to be very much choice in regard to the type of bearings used, ball bearings and sleeve bearings seem to serve equally well provided they are properly oiled. Ball bearings are, however, usually provided to take the thrust or to carry the weight of the impeller of a vertical pump. The part of the shaft that passes through the stuffing box should be of bronze or covered with a bronze sleeve otherwise difficulty will be experienced in keeping the packing in condition. This stuffing box is usually provided with a water seal, although grease seals and special devices are sometimes used. In water pumps the water for the seal is usually taken from the volute of the pump. With sewage pumps, however, this is not advisable for the solids in the sewage are apt to clog the small passages and also because the grit in the sewage will reach the packing and cut the pump shaft. To avoid the possibility of the pollution of the clear water with sewage, the water must usually be taken from a constant level tank supplied from the water lines and not directly from the lines themselves. With double suction and open impeller pumps, if there is a suction lift, there will probably be vacuum on the pump side of the stuffing box and the water seal serves to prevent the entrance of air. With end suction pumps, with enclosed or semi-enclosed impellers, there may be a pressure on the pump side of the stuffing box. The water seal then serves to prevent the grit in the sewage from reaching the packing and cutting the shaft. The pressure on the water seal should of course be greater than the sewage pressure.

Centrifugal sewage pumps will operate satisfactorily if set as high as 15 feet or even a little more above the sewage level, but in such cases special priming devices must be provided for the ordinary method of priming, by filling the suction from the discharge line, cannot be used because it is inadvisable to attach a foot valve to the bottom of the suction. While special priming devices can be used, it is better, if possible, to locate the pumps below the level.

Efficiency and Head

The non-clogging centrifugal pumps will generally give over all efficiencies varying from 35 per cent for the smaller sizes to 65 per cent for the larger pumps. The lift of sewage pumps is usually low and most of the pumps are designed for heads under 40 feet but pumps can be obtained that will lift sewage against heads as high as 75 or even 100 feet. Beyond this head two stages are needed, but the ordinary type of multistage pump used for water cannot be used because of the many sharp turns and the narrowness of the water passages. At a station where it was necessary to raise sewage 180 feet, two pumps connected in series on the same base, with the motor between them, have been used successfully. The overall efficiency of the unit was found on test to be 35 per cent.

Hydraulic Characteristics of Centrifugal Pumps

With centrifugal pumps, careful attention must be given to the hydraulic characteristics of the pumps in designing a pumping station, particularly if the discharge line is of any considerable length.

If an engineer desires a pump to deliver 300 gallons per minute against a head of 20 feet he is very apt to add a little to the head for safety and specify that the pump shall deliver 300 gallons a minute against a head of say 21 feet. A typical 4-inch pump will meet these specifications almost exactly, and will require about 2¼ horsepower to operate it and, a 3-horsepower motor will serve satisfactorily. If, after installation, it is found that the actual head is only 18 feet instead of 21 feet, due to some unforeseen condition or due to the fact that the engineer figured his friction for 10 year old pipe and the pipe is actually new pipe, this pump will deliver 600 gallons per minute instead of 300 gallons per minute and will require 3½ horsepower. The 3-horsepower motor will in that case be overloaded. Conditions similar to this occur very frequently and it is best in all cases to require the motor to be of sufficient size to operate the pump without overheating at any head between the maximum and zero.

When two or more pumps are connected to the same discharge line, the reverse condition often occurs. If two pumps, having the characteristics mentioned above, are connected to a single discharge line, one pump operating alone will discharge 300 gallons per minute. When both pumps are put in operation the friction loss in the discharge line will of course increase. With the particular 4-inch pump just mentioned, if this increase is only about 1½ feet (from 21.0 feet to 22.6 feet) the discharge of each pump will be reduced to 200 gallons a minute or the total discharge of the two pumps will be about 400 gallons per minute or only slightly greater than the discharge of one pump. For this reason it is often found desirable, especially with long discharge lines, to arrange the controls so that one pump will shut off entirely and the second pump, designed for a larger capacity and a little higher head, will start when the sewage flow exceeds the capacity of the first pump.

Multispeed motors are sometimes used to meet these conditions but such motors operate only at certain fixed speeds and it is generally difficult to design the pumps to obtain the desired capacities at these motor speeds. Any desired speed may be obtained by using variable speed motors, but if this is done the losses in the resistances greatly reduce the overall efficiency of the pumping equipment.

At the Harlem Valley State Hospital pumping station which contains 8 4-inch 450 gallon per minute pumps, a special arrangement was used. As each additional pump starts the friction loss in the discharge line increases approximately 6 inches. The controlling float and float switches are so arranged that as each additional pump starts the sewage level in the suction well is automatically allowed to rise 6 inches. Thereby, the total head, and consequently the discharge of each pump, always remains the same and has proved a distinct advantage.

Suction Line Difficulties

There are several matters in connection with the arrangement of centrifugal pump suction lines, particularly where there is some suction lift, which, while they seem very simple, have caused engineers and operators considerable trouble. There must be no high point in any suction line where air or sewage gases may accumulate. When the pump is started the accumulated air will expand, flow to the pump, and stop its operation. The reducer at the pump must for this reason always be an eccentric reducer with the flat side up. Connections to a

common suction header must for the same reason be made at the top of the header and not at the center of the side. In some extreme cases it has even been found necessary to place the suction valves horizontally so as to avoid the accumulation of air in the bonnets. Common suctions, that is, single suction lines to which two or more pumps are connected, are a source of trouble in many cases where there is a suction lift, and wherever possible should be avoided. It is often difficult in such cases to make each pump take its share of the load. When one pump is in operation it is often impossible to start the second without shutting down the first and starting both together. A slight leak in the stuffing box of one of the idle pumps will many times admit enough air to interfere with the operation of the other pumps. Even when the pump that is not to be operated is entirely shut off, air will frequently accumulate in the riser from the common suction to that pump and will expand when the other pump or pumps are started and enter them and prevent them from operating.

Part II—Sludge Pumping[2]

Pumps designed for moving or lifting sewage sludge may, in general, be divided into two distinct classes, displacement pumps and centrifugal pumps. Since these two classes differ radically in their design and operation and present entirely different problems for those in charge of them, it is necessary to consider them separately. The advantages and disadvantages of each class are matters which engineers and operators are not entirely agreed upon. Displacement pumps are unquestionably more easily primed than centrifugal pumps when there is a suction lift and will probably handle small quantities of sludge more readily than centrifugal pumps, but beyond this it is doubtful whether the advocates of either class will admit the superiority of the other.

Displacement Pumps

The modern displacement pumps used for handling sludge are always of the single acting reciprocating type, and are usually electric motor driven plunger pumps having one, two or more cylinders. The makes most commonly used generally have cylinders about ten inches in diameter and strokes adjustable from about two to five inches. The pumps are connected to the motors by gears, belts or chains and the motion transmitted to the pistons by walking beams or eccentrics. Each manufacturer apparently believes that the transmission used by him is the best, but in practice there seems to be little difference.

Transmission

Certain matters in connection with the transmission are, however, of importance. If it is desired to have the pump run smoothly it is usually best to keep the speed of the main pump shaft below about thirty-five revolutions per minute. This gives a piston speed of thirty feet a minute or less, a low figure as compared with the usual figures for water pumps; but the strokes of these sludge pumps are very short and the frequency of the reversals seem to be of more importance than the actual piston speed. Pumps of this type are generally arranged so that the length of the stroke can be changed by shifting an eccentric or, which amounts to the same thing, altering the length of the crank arm. This makes it possible to obtain several different rates of discharge, but experience indicates that the use of the shorter strokes is not always entirely satisfactory. The pumps in most cases do not operate as smoothly with the short strokes as with longer ones, the slip is greater and the efficiency lower. The use of multi-speed motors and variable speed transmissions, although more expensive, afford a more satisfactory and efficient method of changing the pump capacities to suit the conditions, and where available should be used in preference to changing the length of the stroke.

Packing

Like all reciprocating pumps the sludge pumps must be packed to prevent leakage between the pistons and the cylinders, and this packing is one of the most frequent causes of trouble in the operation of the pumps. The packing may be either on the cylinder or the piston. Generally it consists of from 4 to 6 rings of ½ inch to ¾ inch packing held in place by an adjustable metal ring or gland. If the packing is too tight, scored pistons or cylinders and broken shear pins will be the result. If the packing is too soft, too loose or improperly placed it will leak, and since the pumps are outside packed this means that the pumps and probably the floor around them will soon be covered with sludge which does not add to the attractiveness of any sewage treatment plant. Opinions differ as to the most satisfactory type of packing. Generally a square braided flax packing serves as well as any. A graphited packing may be desirable to prevent unsatisfactory conditions due to rust where the pumps stand idle for a considerable time. Rawhide packing is satisfactory but does not seem to be necessary except with certain chemicals. The packing must fit and must be properly placed. In cutting the packing it is well to use a template into which a piece of packing exactly the length of one ring can be fitted. In this way each ring will have the same length and the same bevel. The method of oiling the packing varies with the make of the pump. Generally it is found that a fairly heavy oil such as a good grade of cylinder oil gives the best results. Oils known as "500 W" and "Marine Pump Oil" are in common use. A light oil disappears very rapidly. Under continuous operation the packing will usually last about 3 months, but under intermittent operation it may last a year or two. Manufacturers have recently been giving more attention to the finishing of the pistons and cylinders, in some cases grinding them. This has made it easier for operators to keep sludge from leaking between the pistons and cylinders but has not done away with the necessity for careful packing.

Valves

Each cylinder of a reciprocating pump necessarily has an inlet valve and a discharge valve. These valves may be weighted flap valves or ball valves. Each type has its advocates although at present the ball valves seem to be preferred by most operators. Spring loaded poppet valves which operate satisfactorily in water pumps obviously cannot be used for liquids containing an appreciable amount of solids. No mater which type is used the valves will require some attention from the operator. With raw sludge the valves may require cleaning from two to three times a day to two or three times a week. If the pump is handling activated or secondary tank sludge, cleaning will of course be required less frequently. Fibrous material will collect under the hinges or flap valves and rags will accumulate under ball valves holding the valves off their seats and rendering the pump inoperative. Metal flap valves wear at the hinges so that the flap will not seat properly and soon require replacement. Valves of rubber with rubber hinges clog less frequently than metal valves because of their smoother surfaces, but the rubber hinges are inclined to swell and split and it is difficult to turn them back for cleaning. Ball valves are usually of rubber moulded on an iron core. If they are to operate satisfactorily, careful attention must be given to the quality of the rubber, the balance of the valve and the weight of the core. Valves made of a poor quality of rubber will sometimes swell and stick, and cases are on record where the rubber has softened so as to allow the ball to be forced into the piping stopping the pump. The valve must balance or the ball will always seat at the same point and wear rapidly. The weight of the valve must be suitable for the conditions under which it will operate.

Pounding or Knocking

One of the most frequent complaints heard regarding the operation of reciprocating pumps is that they knock or pound. This is due to various causes. Since sludge lines are usually comparatively short, the high water hammer stresses sometimes encountered at water pumping stations are seldom of importance, but the flow of liquid in the suction and discharge lines must be stopped and started with each stroke (single cylinder pump with no air chamber), the valves must close and in doing so strike the seat, and each stroke causes a reversal of stresses in the piston, the crank and the connecting mechanism. These conditions cause pounding which cannot in all cases be entirely eliminated. The subject is too complicated to be discussed in detail here.

The stresses and pounding due to starting and stopping the flow in the discharge line can be generally alleviated by the use of an air chamber, but the air chamber must be large to be of any value. The same thing is true of the suction line, although an air chamber is not so frequently used at this point. One manufacturer provides a small air inlet valve on the suction of the pump which if properly adjusted seems to make the pump operate more smoothly, but of course somewhat reduces its capacity and efficiency.

Valve slam is sometimes due to the fact that the direction of flow through the valve reverses and acquires considerable ve-

[2]From a paper presented before the joint meeting of the N. Y. State and New England Sewage Works Association.

locity before the valve closes. This velocity may then carry the valve to its seat rapidly enough to cause a heavy blow when the motion of the valve and the liquid is suddenly stopped. This reverse flow of water through the valve is of course slippage and reduces the efficiency of the pump as well as causing valve slam. The valve should, for these reasons, be heavy enough and so arranged as to close as quickly as possible, and yet not interfere with the operation of the pumper by reducing the area of the ports.

The knocks due to the reversal of stresses in the different parts of a pump are the same as those which occur in any reciprocating machine. If there is any lost motion in a main bearing, eccentric, wrist pin or other part there will be a knock each time the stresses are reversed. The remedy is obvious. All bearings must be properly adjusted and kept properly lubricated.

Centrifugal Pumps

Centrifugal pumps, if they are to handle sludge successfully, must pass solids without frequent clogging. This makes it necessary to use end suction pumps at least 4 inches in size with as few bends and sharp corners in the liquid passages as possible. The impellers usually have only two blades with long sweeping curves and are either fully enclosed or have a shroud on one side. Open impellers clog very rapidly when the liquid contains rags. Even with these precautions, it is generally desirable to have hand holes or other means of access to the interoir.

One pump manufacturing company equips its centrifugal sludge pumps with a screw to force the sludge into the pump and to macerate the solids as they enter. Pumps of this type have been in operation at a number of plants for several years. Similar devices are being made by some other manufacturers but have not as yet come into extensive use.

Capacity and Regulation

A 4-inch centrifugal pump will readily discharge 100 gallons a minute and in some cases as low as 50 gallons a minute, but if capacities below this are necessary some difficulty is apt to be experienced unless provision is made for reducing the speed below that which can be obtained by a direct connected motor. Variations in head, of course, cause variations in the capacity of a centrifugal pump and if a definite quantity of discharge is required some method must be provided to compensate for these variations. In many plants it is necessary to change the quantity of sludge delivered from time to time and provision must be made for so doing. Theoretically, throttling might accomplish these ends, but throttling is not desirable when pumping sludge. If careful adjustment of the quantity of sludge delivered is necessary the only practical method of regulations seem to be to change the speed of the pump. Variable and multi-speed motors will do this within limits but are not as satisfactory as some of the variable speed transmissions available. These transmissions, while expensive, make it possible to obtain almost any capacity within the limits of the pumps. It must not be forgotten, however, that a centrifugal pump will give its highest efficiency at one definite speed and capacity and that as the speed and capacity are changed the efficiency may fall off rapidly. This is naturally of more importance when the pumps are in continuous operation than when they are operated intermittently.

Priming and Seals

Centrifugal pumps will not handle air and when they are used careful consideration must always be given to priming and to the elimination of air pockets in the suction line. To facilitate priming, centrifugal pumps should if possible be set below the surface of the liquid in the suction well. If the pump must be set above the level of the liquid some means of priming must be provided. Foot valves which are often used with water pumps will not serve satisfactorily with pumps handling sludge. Vacuum systems are available and operate satisfactorily if kept in condition, but mean added expense of installation and more equipment for the operator to maintain.

The impeller shaft of every pump of this kind must pass through the pump casing and therefore requires a stuffing box to prevent leakage. On water pumps these stuffing boxes are provided with water seals and the water taken from the pumps. The material handled by a sludge pump is not, however, suitable for the seals and water must be obtained from some source. A direct connection to the water system cannot be used due to the danger of polluting the water supply with sludge. If the building is high enough a small tank fed over the top and controlled by a float valve may be used as a source of water. The height of the tank must be greater than the discharge head of pump or the sludge will be forced into the packing and probably result in the scoring of the shaft. If the tank cannot be set high enough, a small pump may be used to supply water to the seal. Grease seals and other special devices are sometimes used but are not as satisfactory as water seals.

Maximum Flow Gage for Sewers*

The accompanying sketch pictures the type of maximum flow gage, which has been installed in five manholes in the village of Shorewood in Milwaukee County, Wisconsin.

Metcalf and Eddy, in "American Sewerage Practice" (Vol. 1), under Maximum Flow Gages, describe a device that is substantially a stick with small vials attached along its length and inserted into a perforated pipe. The level of the mouth of the highest vial found full indicates the height to which the sewage has risen in the manhole. This design, however, has its disadvantages. First, the vials are breakable and entail considerable trouble in replacing. Second, it can not be used where the velocity exceeds eight feet per second.

The improvements in the Shorewood installation are:

First: It is cheap—the entire gage, made by a tinner and ready to install, costs very little.

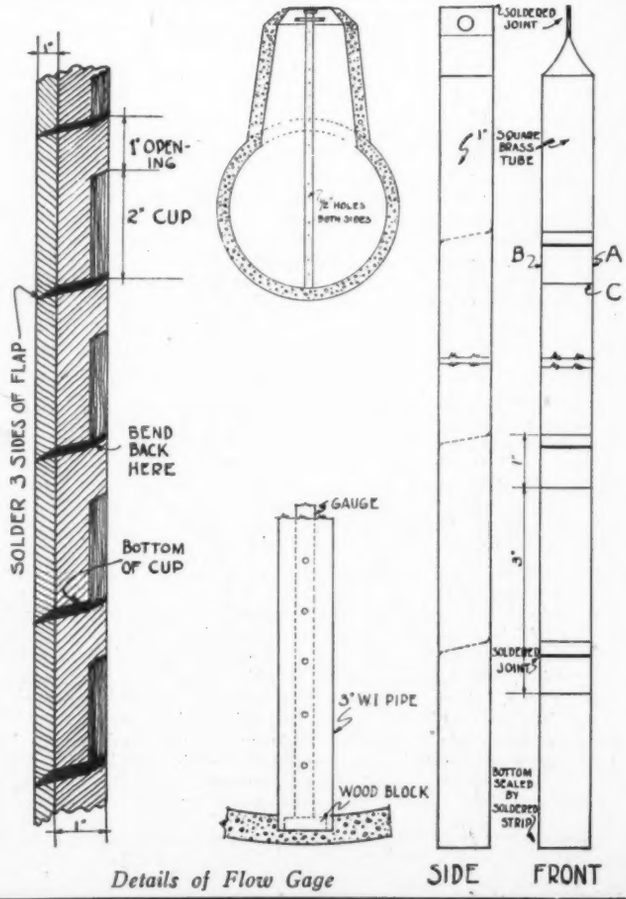
Second: It is not breakable and may be used in sewers regardless of velocity. Being made of brass or copper it is immune to corrosion.

A brief description may be helpful.—This gage is made of one inch (square) brass tubing, with one face (C on sketch) cut through at predetermined spacings. In the Shorewood design it is three inches. Then the corners are ground off on a power grinder to make edges A and B. The resulting flap is bent back and soldered in place to form the bottom of the pocket above. The block of wood is to raise the gage to the elevation of the invert of the sewer. The spacing of the pockets and the width of the mouths may be varied to suit circumstances. A perforated 2 in. W.I. pipe protects the gage.

In practice the gage has proven reliable and has served satisfactorily through several storms when the sewers were surcharged.

Credit for this design belongs to George Dewey Simms, Assistant Village Engineer, Shorewood, Wis.

*Contributed by Julius Lucoff, Milwaukee, Wis.



Details of Flow Gage

CHICAGO PUMP COMPANY

2349 Wolfram St., CHICAGO, ILLINOIS

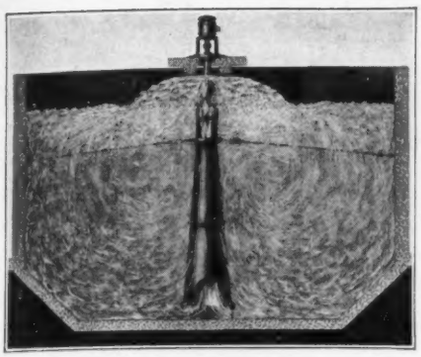


Fig. 2312—Mechanical Aerator
Flora, Ill., installation giving 98% reduction of domestic sewage of 570 p.p.m., 24-hr. average (5-day) B.O.D. Power consumption of 0.337 Kilowatt hours per lb. B.O.D. reduced, measured on primary effluent of 330 p.p.m. B.O.D. Ask for Bulletin 128-L.
Chicago Pump Co. also manufactures the Combination Aerator - Clarifier which performs straight aeration and clarification simultaneously in a single tank. Ask for Bulletin 128-K.

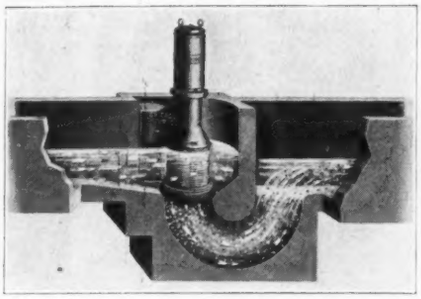
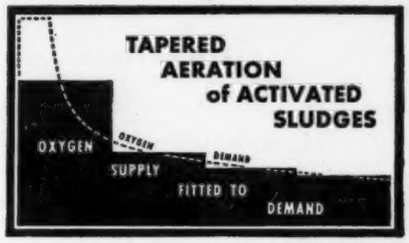
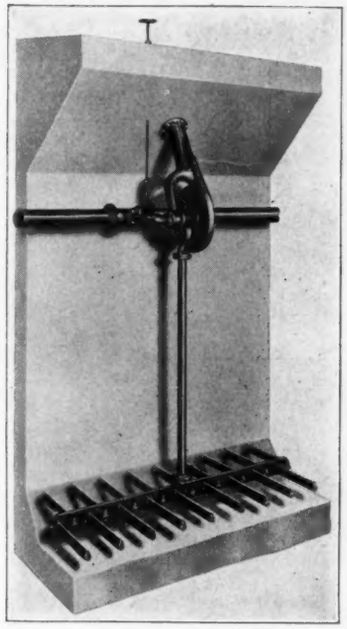
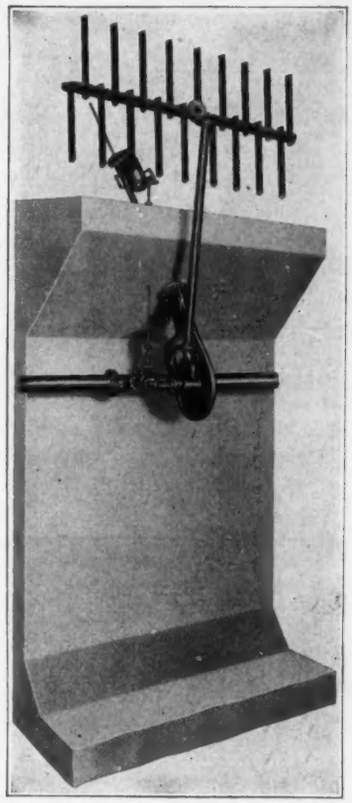


Fig. 2202—Comminutor
Eliminates screenings and screenings disposal—No burial; No incineration. Cuts coarse sewage matter into small settleable solids without removal from the channel.







Figs. 2905 (left) and 2910 (right)—Swing Diffusers
Controlled aeration for the Activated Sludge Process. Diffuser tube assembly can be raised to tank walk. Simple regulation of air supply from tank walk. Tube cleaning without dewatering tanks or interrupting operation.

Fig. 1731-1—Vertical Open-shaft Non-Clog Pump
Universal Flexible Couplings in shaft compensate for misalignment. Ask for Bulletin 126.

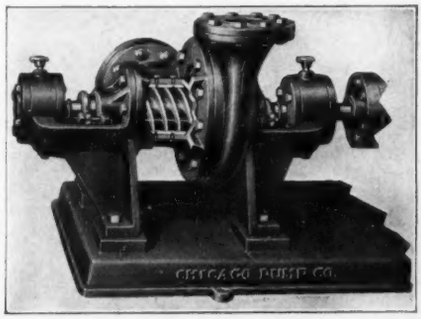


Fig. 1860—Scru-Peller Primary Sludge Pump
Screw conveyor in the suction ahead of the impeller. Stellited cutters prevent clogging. The capacity can be varied instantly. Ask for Bulletin 128-D.

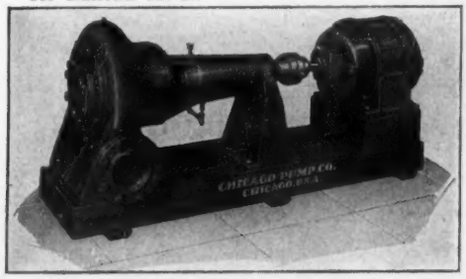


Fig. 1774—Horizontal Non-Clog Pump
Being mounted directly on base prevents pump being pulled out of alignment by long lines of piping. Ask for Bulletin 127.

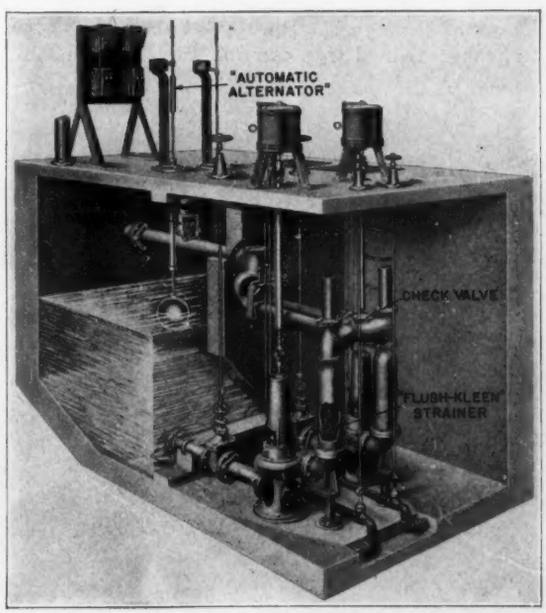


Fig. 2038—Flush-Kleen Sewage Pumping Station
Requires no attention. NEVER CLOGS. Automatically backwashes strainer. Keeps solids from basin and pumps. Impeller handles water, only. Coarse sewage matter is stopped by Flush-Kleen strainer and is flushed out through discharge pipe. Check valve prevents discharging back through inlet line. Ask for Bulletin 122.

THE JEFFREY MANUFACTURING COMPANY

SANITARY ENGINEERING DIVISION

996-99 North Fourth Street, Columbus, Ohio

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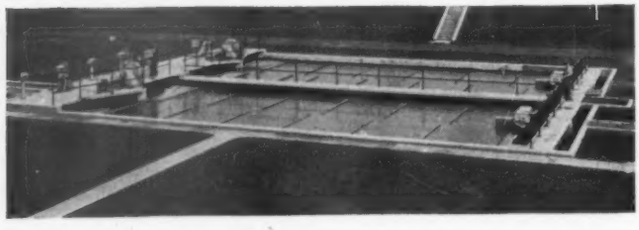
EQUIPMENT: Sludge Collectors, Bar Screens, Scum Collectors, Grit Washers, Floctrols, Chemical Feeders, Screenings Grinders, Garbage Grinders, Sludge Elevators, Conveyors, Bucket Elevators, etc. Catalog No. 703.

SLUDGE COLLECTORS (Conveyor Type)

Designed especially for the removal of sludge from rectangular sedimentation tanks, which give efficient and uniform distribution of influent over the cross section of the tank. Jeffrey Collectors, the simplest type of conveyor, consisting of two strands of a heavy pintle type Supermal Chain pass over sprockets at tank corners. Wooden scrapers fastened to the chain, drag along the bottom of tank, pushing the settled sludge ahead into hoppers at influent end. Large carrying capacity permits intermittent operation.



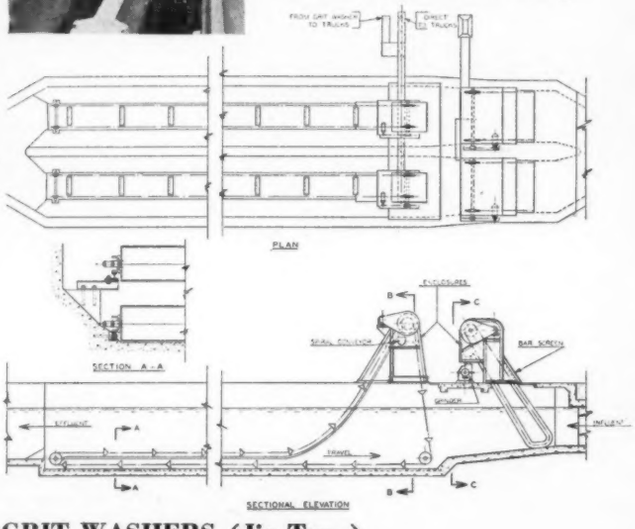
Two double compartment primary settling tanks equipped with Jeffrey sludge removal equipment. Cross type scum remover is shown at the right end of tanks.

View above illustrates an excellent weir construction for secondary basins. View at the left shows covered basins with cross collector for sludge. The cross collector can be driven by a take-off from one of the main collector shafts.

GRIT WASHERS (Conveyor Type)

Grit channel conveyors either scraper or V-bucket type offer the most efficient method of grit removal. Either is a continuous conveyor which not only washes and gathers grit but elevates it for discharge. It is not necessary to allow for diminishing cross-sectional area if the grit channels are equipped with Jeffrey conveyors.

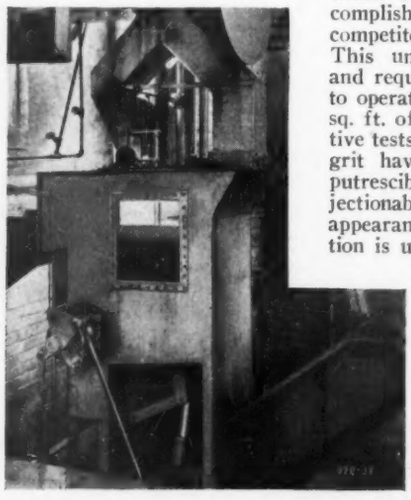
The scraper type is shown above; the V-bucket at left and in drawing.



GRIT WASHERS (Jig Type)

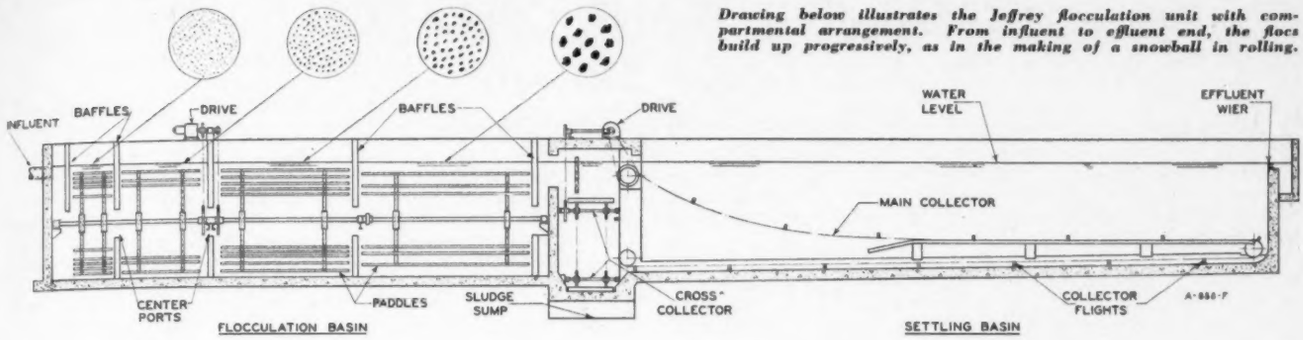
By adapting the Jeffrey diaphragm jig, used for years for cleaning and washing coal, to the washing of sewage grit, we have devised a jig-type grit washer which is so outstanding in accomplishment that it has no competitor.

This unit is fully automatic and requires less than 2 H. P. to operate. It occupies only 24 sq. ft. of floor space. Exhaustive tests have produced washed grit having less than 1% of putrescible solids, free from objectionable odors or unsightly appearance. Water consumption is unusually low.



The installation view (left) shows the compactness of this grit washer, which consists of a steel compartment, in the bottom of which is a heavy diaphragm caused to assume an up and down motion by means of the motor-driven eccentric shown below it. Detailed views and drawings will be sent upon request.

THE JEFFREY MANUFACTURING COMPANY



Drawing below illustrates the Jeffrey flocculation unit with compartmental arrangement. From influent to effluent end, the flocs build up progressively, as in the making of a snowball in rolling.

FLOCTROLS

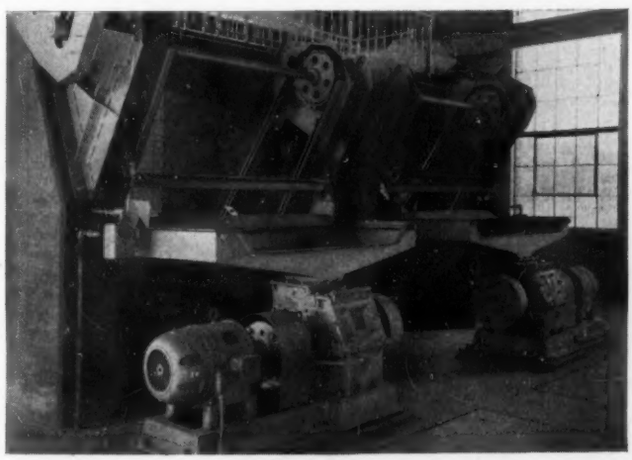
Jeffrey engineers have developed a new flocculation process for the treatment of turbid waters, which obtains substantially complete removal of suspended and colloidal particles in the sedimentation basin, using a minimum of chemical coagulant.

The unit is a rectangular, multi-compartment tank having a paddle wheel mechanism (see line drawing above) in each compartment. The process causes the solid particles to move relative to each other and keeps them in suspension throughout the length of the tank. Degree of agitation is decreased in each step of the treatment.

This new Jeffrey process, which can be used for treating sewage and waste water as well as for water softening and in industrial processing, has these advantages: lower first cost, minimum chemical cost, progressive build-up of stable flocs, continuous sludge removal in separate basin, elimination of short-circuiting, no mechanical adjustments for wide variation in character of influent. Send for engineering data.

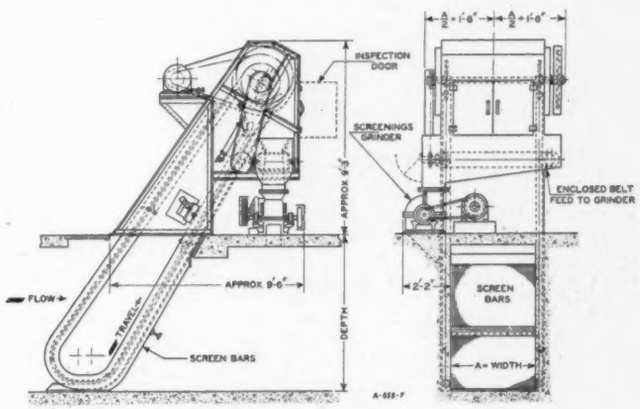
SELF-CLEANING BAR SCREENS AND GRINDERS

With the use of screens and grinders, screenings are collected and disposed of by reducing them to a pulp and returning them to the sewage, thereby solving the problem of final disposal of the screenings. Operation of screen is entirely automatic. Grinder can be either hand or belt fed.



Two bar screens arranged with receiving hoppers for hand feeding screenings to the two grinders. One grinder can be made to serve two or more screens if desired.

The Jeffrey bar screen has a number of features superior to those of any screen offered for this class of service. No sprockets or shafts at bottom of channel, clear opening from side to side in submerged portion, rake teeth pass entirely through the screen, scraper enters sewage back of the accumulated refuse, travel can be reversed, operates continuously or at intervals, electric controls of weather-proof construction.



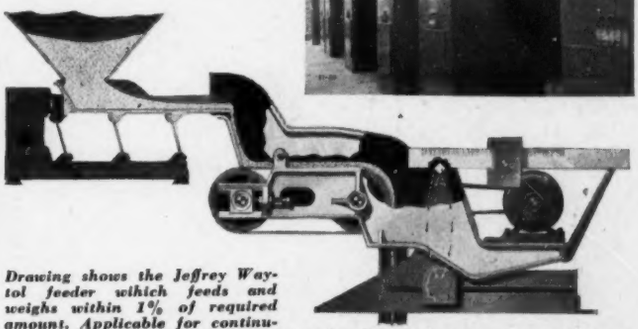
Drawing shows Jeffrey bar screen and grinder details with belt feed.

CHEMICAL FEEDERS (Patented)

Jeffrey-Traylor electric vibrating feeders are well adapted for the feeding of dry chemicals for water and sewage treatment plants. Accurate feeding makes it possible to use the smallest amount of chemicals with a resultant saving in costs.

Simple design with freedom from wearing parts is especially advantageous where continuous operation is essential. Rate of feed can be varied over a wide range. Catalog No. 650 completely describes and pictures Jeffrey-Traylor vibrating feeders.

A group of eleven Type 100 J-T Waytrol feeders (right) feeding chemicals in a water works.



Drawing shows the Jeffrey Waytol feeder which feeds and weighs within 1% of required amount. Applicable for continuous weigh-feeding, proportioning and batching. A size and type to meet your requirements.

HOURLY LOAD VARIATIONS IN RELATION TO SEWAGE TREATMENT PLANT OPERATION

By ELSON T. KILLAM

Consulting Engineer, New York City

The wide variations in the hourly load arriving at sewage treatment plants, due to the combined effect of variations in sewage strength and in rate of sewage flow, have previously been discussed by the writer.[1]

Data then available were confined to two plants, both located in Georgia. Investigations recently conducted on two systems in New Jersey involving widely different conditions than those of the two systems originally described, indicate surprisingly similar load variations.

Tests of 24-hour duration with frequent flow readings and separate analysis of hourly or two-hourly samples emphasize the following conditions in these four systems:

(1) A substantial portion of the total daily load arrives at the plant in a comparatively short operating period—see curves.

(2) The hourly variations and per cent of the total daily load arriving at the plant in any given period are not markedly different regardless of whether the load be expressed in terms of flow and B.O.D. content—or, expressed in terms of flow and suspended solids content.

(3) Load variations from hour to hour are surprisingly uniform regardless of the size of the system or other factors which might normally be expected to create widely different conditions.

(4) Hourly distribution of load and variations therein have important effects on plant efficiency and on operating procedure with many types of treatment plants, particularly chemical plants. These variables emphasize the desirability of providing for flexibility in design to allow variable operation.

[1] "Hourly Load variations as a Factor in Sewage Treatment Plant Operation"—WATER WORKS AND SEWERAGE; July, 1934; pp. 237-240.

Studying the Load Variations

A convenient method of summarizing sewage load variations is by means of cumulative load curves. To obtain data for such a curve, samples should be collected throughout a full 24-hour period, preferably at intervals of 15 minutes or ½ hour. These samples should be proportionate to the flow and each group of samples comprising a period of one or two hours' duration should be separately analyzed. It is also essential to take flow measurements at frequent and coincident intervals. In this way the total pounds of suspended solids or B.O.D. arriving at the plant during each hour of the day, may be ascertained. Cumulative load curves may then be constructed by selecting, first,

TABLE NO. 1—DATA RELATIVE TO CUMULATIVE LOAD CURVES

Curve Number	Location of System	Type of District Served	Average Flow—M.G.D.	Estimated Tributary Population	Date of Test Period	Distance from Sampling Point to Most Remote Point in System—Miles	Method Flow Measurements (*)	Data Relative to Samples
"A"	DECATUR, GA. (Shoal Creek Outlet Sewer)	Strictly Residential: Separate System	0.167	2,200	4 p. m., Sat., Oct. 28 to 4 p. m., Sun., Oct. 29 1933	2.5	90 deg. V Notch Weir	(a)
"B"	RAHWAY, N. J. (Rahway Valley Joint Trunk Sewer for 7 Municipalities)	Separate System: Residential, with some Industries and some Business Districts	1.84	23,000	3 p. m., Mon., July 23 to 3 p. m., Tues., July 24 1934	7.8	90 deg. V Notch Weir	(a)
"C"	ELIZABETH, N. J. (Elizabeth Valley Joint Trunk Sewer for 12 Municipalities)	Separate System: Residential, with some Industries and some Business Districts	14.19	228,000	2 p. m., Thur., Aug. 2 to 2 p. m., Fri., Aug. 3, 1934	18.0	Venturi Meter	(b)
"D"	ATLANTA, GA. (Main Sewer Entering Peachtree Creek Plant)	Combined System; Residential, with some Industries and some Business Districts	15.22	110,000	8 a. m., Fri., May 3 to 8 a. m., Sat., May 4, 1933	8.0	Recording Gage at Station Rated by Current Meter	(a)

* All Flow Readings at half-hour intervals.
(a) Samples collected at half-hour intervals—each group of four composited and analyzed.
(b) Samples collected at half-hour intervals—each group of two composited and analyzed.

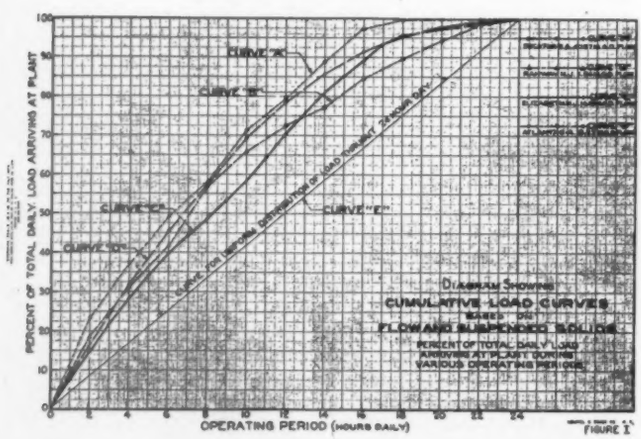


Fig. 1—Cumulative Loads, Based on Floc and Suspended Solids

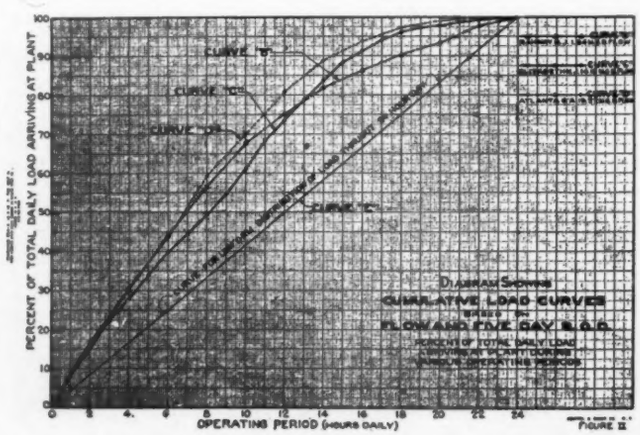


Fig. 2—Cumulative Loads Based on Flow and 5-Day Oxygen Demand

the hour at maximum load, and subsequently taking each consecutive hourly load in order of descending magnitude, and plotting of 24-hour curve. Loads expressed in terms of flow and suspended solids content, or flow and B.O.D. content, or both, may be used for the study.

Typical examples of such curves, showing data for the four system investigated, are shown in Figures 1 and 2, the former being based on load determined by suspended solids content and flow, and the later upon B.O.D. and flow.

Statistics, showing the type of system, average daily flow, tributary population, and other information, for the four systems investigated, are shown on Table 1.

Similarity in Load Variations

In view of substantial differences in type and size of the four systems referred to in Table 1, the relatively small difference in the load developed in any given number of hours in each of the systems, is of especial interest.

The Decatur (Ga.) system, for instance, involved a sewage flow of only 0.16 m.g.d. with a population of only 2,200 people in a strictly residential area, and with the most remote point in the area served only 2½ miles from the point of sampling on the trunk sewer.

On the other hand, the Elizabeth Valley System involved a total flow of 14.19 m.g.d. from a tributary system comprising several hundred miles of sewers serving 228,000 people. Remote portions of the system are at least 18 miles distant from the point at which flow measurement and samples were taken.

It might well have been expected that in such an extensive system as the latter, the variations would be smoothed out and greatly reduced in magnitude before the sampling point was reached by the passing flow. Comparison of all four curves, however, indicates that in no instance, within a fixed number of hours of operation, does the total cumulative load arriving at the plant vary by more than 13 per cent. Examination of the curves also discloses that the distribution of the load, based on suspended solids, agrees very closely with the load based on 5-day B.O.D.

What It Means

The similarity of these curves indicates that load variations in substantial proportions may be expected on every sewerage system. These variations and their effects are accordingly important in the design and operation of sewage treatment plants. in the measurement and evaluation of treatment plant efficiency; and, in the collection of river samples below sewer outlets during investigations of the pollution of receiving streams.

KILLING ROOTS IN SEWERS WITH COPPER SULPHATE

By J. W. McAMIS

Superintendent Water Works and Sewerage, Greenville, Tenn.

Roots give a great deal of trouble in the smaller sewers, by causing stoppages wherever they may happen to find an entrance into the pipes carrying domestic sewage.

For four or five years now we have been using copper sulphate to combat this trouble.

We have a man whose duty it is to visit each manhole in the system at least once each month, looking for stoppages. He carries along on these trips a small bag or bucket of copper sulphate and drops a small handful of crystals down into the flowing sewage wherever he finds that the stoppage is downstream.

After a reasonable amount of experience in this work a man can tell pretty well where trouble is to be expected in the near future, by the nature of the flow of the sewage and by the conditions in the bottom of the manhole.

In cases where stoppage is due to roots, sewage will back up into the next manhole above during periods of greatest flow during the day and will recede during periods of low flows. This condition may exist for days or possibly weeks before the sewage begins to overflow the top of the manhole and run into the street. By throwing in the copper sulphate crystals *while the sewage is still flowing*, a sufficient concentration of the poison will usually reach the seat of the trouble to eliminate it before the stoppage is complete.

At Greenville, we have the same man doing this work that looks after the disposal plants and he tells me that he can predict almost exactly when the balls of roots will turn loose and come down to the treatment plant following the copper treatment.

Since we have been using this scheme it is a rare day when we have to send out a truck with sewer-rods and other equipment to open up a stopped sewer.

Regarding the exact quantity of the sulphate required for good results, I have attempted no determination of the necessary concentration of copper sulphate. However, it is my opinion that the length of the contact period is a more important factor than the actual concentration of the copper sulphate. To illustrate; the ideal condition seems to be where a small flow of sewage, say two to five g.p.m., is just trickling through a mass of roots. In a case like this a small handful of the chemical applied in the manhole just upstream from the stoppage will do the trick.

If the flow is greater, as determined from looking in the manhole just below the stoppage, greater quantities and possibly repeated applications would be necessary. If it is kept in mind that it is time of contact that is important, rather than the amount of copper sulphate, no trouble should be experienced in carrying out this operation.

Another important point to remember is that it is useless to apply the copper sulphate in a sewer that is completely stopped, for unless there is at least a small flow of sewage through the obstruction there is no chance for contact between the roots and the copper solution. Sewer rods would be the only remedy here—at least to start some flow through and allow the copper to reach the roots. (Since it is only necessary to kill the small root which enters the sewer, and not the great mass of roots branching from it, the important factor is that of reaching the feeder root with the killing chemical. Then, the flow pulling on the large heavy "brush," causes the weakened base root to break. Prechlorination of sewage has been found to produce the same results on root infected sewers but is not so simply applied as the copper treatment.—Ed.

LINK-BELT COMPANY

Manufacturers of Equipment for Sewage *Treatment and Water Purification Plants*

PHILADELPHIA 2045 W. Hunting Park Ave. | CHICAGO 300 W. Pershing Road | LOS ANGELES 361 S. Anderson St. | INDIANAPOLIS 220 S. Belmont Ave. | ATLANTA 1116 Murphy Ave., S.W.

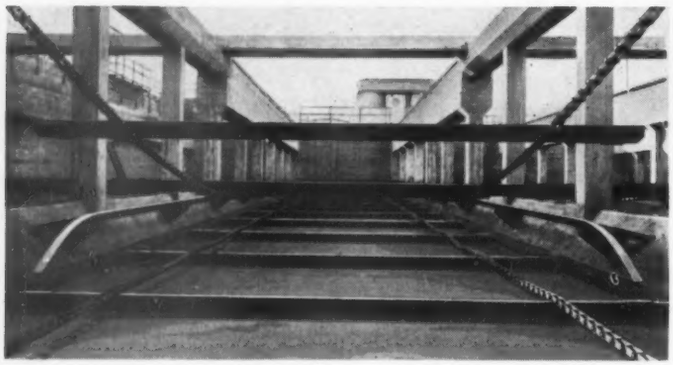
Baltimore..Boston..Buffalo..Cleveland..Dallas..Denver..Detroit..Grand Rapids..Houston..Huntington, W. Va...Kansas City, Mo...Louisville New Orleans..New York..Oakland, Calif...Pittsburgh..Portland, Ore...Salt Lake City..Seattle..St. Louis..St. Paul..Wilkes-Barre

In Canada—Link-Belt Limited—Toronto Plant; Montreal; Vancouver.

7763

PRODUCTS STRAIGHTLINE Collectors; CIRCULINE Collectors; STRAIGHTLINE Mechanically Cleaned Bar Screens; Tritor Screens; Grit Chambers; Tark Fine Screens; Equipment for Flocculation Tanks; STRAIGHTLINE Mechanical Aerators; STRAIGHTLINE Scum Breakers for Digestion Tanks; Elevated Aerators — Elrod System; Rotary and Reciprocating Distributors; Traveling Water Intake Screens; Industrial Waste Screens, and a complete line of elevating and conveying equipment for all materials; power transmission equipment and all accessories.

STRAIGHTLINE COLLECTOR
FOR RECTANGULAR SETTLING TANKS

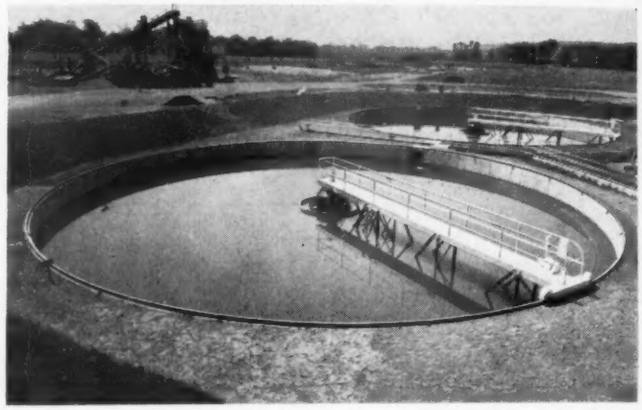


STRAIGHTLINE operation is of proved reliability. Link-Belt units have been in operation for over a decade and many installations are now in service in all parts of the country. They range in size from the smaller type plant as at Tappahannock, Va., with a capacity of 80,000 G.P.D., to larger installations such as Ward's Island, N. Y., with a capacity of 180,000,000 G.P.D., and Southwest Plant, Sanitary District of Chicago with a maximum capacity of 600,000,000 G.P.D.

Many features of the Link-Belt STRAIGHTLINE Collector are patented. Send for Book No. 1742.

32 Final Settling Tanks equipped with STRAIGHTLINE Collectors, Ward's Island Sewage Treatment Plant, New York City. Fuller & McClintock, Consulting Engineers.

CIRCULINE COLLECTOR
FOR ROUND SETTLING TANKS



City of Dayton, Ohio, 4 final tanks equipped with Circuline Collectors. M. D. Tatlock, Consulting Engineer and Superintendent.

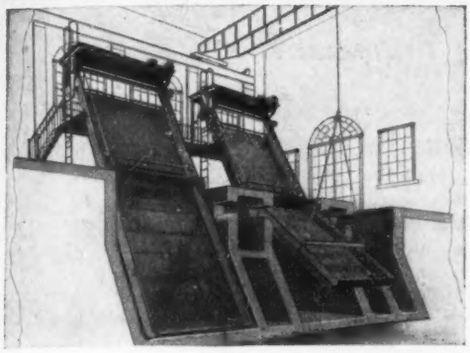
The Link-Belt CIRCULINE Collector provides round tanks with the same important features which have made the STRAIGHTLINE Collector the acknowledged standard for rectangular tanks.

Since the efficiency of a settling tank depends largely upon the means of introducing the influent into and distributing the flow throughout the tank, the CIRCULINE Collector is provided with special features to accomplish this result.

The influent is introduced through an inverted syphon and a vertical pipe, and is discharged at the center of the tank where the flow is deflected downward by a circular solid baffle. A circular perforated baffle then uniformly distributes the flow throughout the tank.

A CIRCULINE equipped tank is provided with a revolving bridge carrying a sludge plow and a STRAIGHTLINE conveyor which positively delivers the settled solids into an annular covered sludge trough from which they are withdrawn. The entire floor of the tank is cleaned of settled solids during each revolution of the bridge, thereby permitting extremely slow movement of the bridge and conveyor, which assures minimum disturbance of settling and of the settled solids. Send for Book No. 1642.

STRAIGHTLINE BAR SCREENS



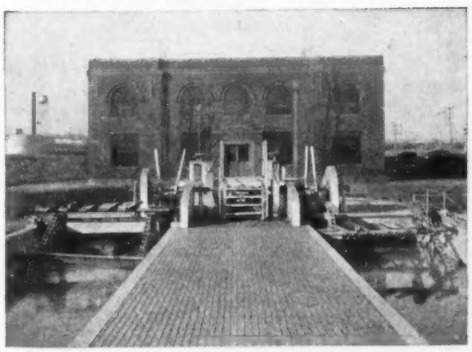
Link-Belt STRAIGHTLINE Mechanically Cleaned Bar Screens have spaced parallel bars on which the larger floating solids in incoming sewage collect, and a mechanically operated rake for removal of the accumulating solids, thus assuring an even flow of sewage through the channel. The machine may be set vertically or inclined, and used in small or large plants.

Send for Booklet No. 1587.

TRITOR SCREENS

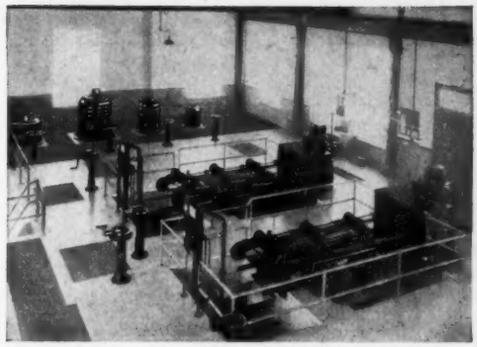
The Link-Belt TRITOR Screen is especially designed for economical use at small size plants. Its main elements are a hopper; a bar screen; and a bucket elevator for removing grit from hopper, the buckets being perforated for drainage. On return run, rake teeth on buckets clean the screen. An adjustable weir regulates currents through hopper. Booklet No. 1587.

STRAIGHTLINE GRIT COLLECTOR AND WASHER



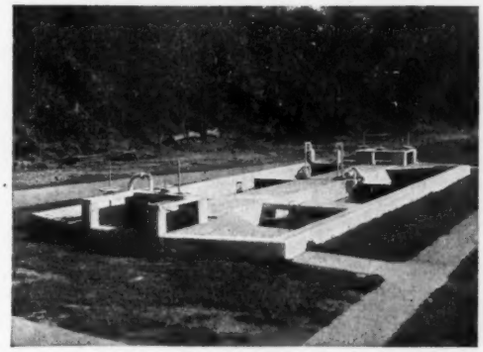
The Link-Belt STRAIGHTLINE Grit Collector and Washer was developed to collect the settled grit, and to wash it free from putrescible organic matter. This unit consists of a settling tank provided with a scraper-type collector; and an inclined washing and dewatering screw to which the collector conveys and discharges the grit at bottom of tank.

FINE SCREENS



For the fine-screening and clarification of municipal and industrial sewage, the Tark Sewage Screen, with its slowly-revolving drum and effective brushing mechanism, has no equal in efficiency in removing suspended solids, and in economy of first cost, operation or upkeep. Effective clarification is assured through the use of very fine apertures, and the elimination of clogging.

EQUIPMENT FOR FLOCCULATION TANKS



Link-Belt mixers of the vertical or horizontal type have proved their value in reducing chemical costs and promoting efficient flocculation in water and sewage treatment plants.

INDUSTRIAL WASTE SCREENS

Waste water from mills and factories often contains objectionable suspended solids which municipalities and health authorities insist upon being removed before the water is discharged into sewers or streams.

The Link-Belt Industrial Waste Screen is an efficient and economical unit for the removal of such solids. The screenings come off the machine with a minimum of moisture. Units are available in several sizes and with coarse or fine screen medium. Wastes from canneries, textile works, steel mills, etc., are handled successfully by these screens. Complete information sent on request.

TRITURATION OF SEWAGE SCREENINGS

Operating Experiences at Oneonta's Sewage Treatment Plant

By WILLIAM W. WATKINS

Engineer and Supt., Water Works and Sewage Disposal, Oneonta, N. Y.

In November, 1933, Oneonta, a city of about 13,000 people, in Southern New York State, put its new sewage treatment plant into operation. The plant consisted of a mechanically operated bar screen, settling tanks with mechanical sludge removal, separate sludge digestion tanks and glass covered sludge drying beds.

Mechanical Screening

When the plant was constructed, the screen chamber was equipped with a "Rex" Mechanical Bar Screen, supplied by Chain Belt Co. of Milwaukee. This screen was operated automatically by time clocks, set to start and stop the screen mechanism at such intervals as experience had shown to be necessary.

Varying conditions in the sewage flow caused too much head loss through the screen and corresponding changes in velocity in the settling basins, so, in 1935, the screen was equipped with a direct operated single float which resulted in a more uniform flow through the screen and the settling basins.

At Oneonta, as at most sewage plants, the real problem has not been that of *removing* the screenings from the sewage, but that of hygienic *disposal* of the screenings removed.

Screenings Disposal

For four and one-half years—when weather conditions permitted—we dug ditches and carted the screenings out for burial in what the men call the "graveyard"—a piece of city-owned property adjacent to the plant and about 200 yards away from the screen. If too much ditch was dug in the fall it caved in before it was used up. After the ground froze it was economically impossible to dig more ditches until spring. Consequently in the spring it was necessary to spend a week or more with a crew of men and trucks getting rid of the screenings that had been dumped but couldn't be buried.

The daily average of screenings removed has varied widely from a maximum of 33.4 cubic feet to a minimum of 4.43 cubic feet. And on one occasion (not storm flow), the total screenings for one day was 66 cubic feet.

With such erratic quantities of screenings it was necessary to keep a large amount of open ditch available at all times, as the operator did not have time to dig his own ditches as required. In addition to the extra cost of ditching it was necessary to have a small truck convenient at all times in order that the full cans of screenings might be emptied and not allowed to accumulate for too long periods.

Burying the screenings took about 2 hours of the operator's time, besides the extra help for ditching and the cost of the truck, making the total cost of handling the screenings about $2.00 per day. Since there is no definite relation between sewage flow and screenings handled, costs per million gallons have little meaning, and therefore have not been recorded.

Early in 1937 it was decided that the cost of handling screenings was too high and that something must be done. In coming to this decision, the element of nuisance admittedly had a bearing. After a survey of the field for satisfactory equipment for shredding or macerating screenings for treatment with the sewage, a "Rex Triturator," manufactured by the Chain Belt Company of Milwaukee, was purchased, and installed in June, 1937, for shredding all screenings removed by the automatic bar screen.

The "Triturator" has been operated every day since its installation. It has saved time for the operator, money for the city, and has gotten results in digestion that we had not expected, but which are very gratifying. The digester gas yields have revealed greater uniformity and higher values, consistently.

Benefits from Trituration

From an operating standpoint, the time required by the operator for putting the day's screenings through the Triturator is about one-half hour to one hour—instead of the two hours or more formerly required to bury the screenings. The operator has the saved time to devote to less objectionable and more valuable duties.

From a sanitary or cleanly standpoint, there is no comparison between the old and the new methods. There are now no cans to fill up, to slop over in trucks, to be washed up when empty, or left to draw flies.

From a strictly monetary standpoint, trituration of screenings shows a money saving benefit which can be actually measured. Some of these follow.

The cost of ditching is eliminated. The use of a truck is no longer necessary. These combined items have figured $1.73 per day at Oneonta. Against this is the cost of power and water consumed by the Triturator. Maintenance is not figured in either case, because such has been negligible. The operator has at least an hour more time available each day, and has been able to do some of the work for which we formerly had to hire extra help from time to time.

At an estimated consumption of 25 gallons of water per minute and forty minutes' operation per day, the cost of water at current retail rates is 13 cents per day. A five horse power motor, running at full load, will consume about 4.5 K.W.H. per hour. This figures twenty-eight cents per day at current rates paid. This makes a total additional cost of forty-one cents per day, not counting in depreciation and interest charges.

Gross Savings by Trituration	$1.73
Less power and water cost	.41
Net savings by Trituration (per day)	$1.32

Operating Cost and Savings

From the time that the plant was put in operation until the Triturator was installed, the average daily quantity of screenings has been 12.88 cubic feet. While there is no way of measuring the screenings, it is reasonable to assume that the same average would still hold. To arrive at the cost per cubic foot of triturating screenings, the maintenance cost will have to be estimated, as there has been no maintenance yet except the resharpening of one set of teeth, ten months of service and feeding to the Triturator all materials removed by the bar screen.

Re-sharpening teeth and reserve for parts replacement	$ 22.00
Water cost per year	48.87
Power cost for year	102.20
Time of operator	124.00
Depreciation at 10% per year	79.00
Total yearly cost	$375.07
Average daily cost	1.03
Total cost per cu. ft. screenings	0.08
Gross yearly cost of burying screenings	$813.00*
Gross yearly cost of triturating screenings	375.07*
Net saving by trituration (per year)	$437.93

*Including operator's time.

This means that the savings will have paid for our Triturator in less than two years' time.

Increased Gas Production

In the ten months since the Triturator was installed, gas production has averaged 7,262 cubic feet per day. The production in the corresponding preceding ten months was only 3,022 cubic feet.

When the weight of screenings is considered in relation to the total amount of settleable solids in the sewage, triturated screenings reaching the digester must be given credit for a calculated 50 per cent of the gas increase, if not more.

From this writer's experience, it can be said, with emphasis, that the successful shredding or grinding of screenings is one of the outstanding advances in sewage treatment of the past five years. No simpler disposal can be imagined than the grinding and return of all screenings to the sewage.

PACIFIC FLUSH-TANK CO.

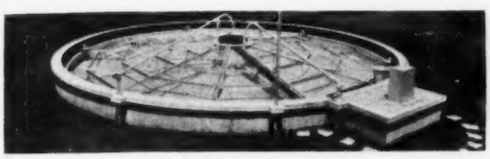
4241 Ravenswood Avenue, Chicago

New York **Charlotte, N. C.** **Los Angeles**

The modern, dependable P.F.T. Line of today has been 46 years in the making—nearly half a century of development work, designing and construction of sewage treatment equipment exclusively.

In that time, P.F.T. has steadily improved its equipment, but we are still learning—research and experimental work in the field are daily adding to our store of knowledge and the findings that result, as in the past, will benefit the science of sewage treatment as a whole.

We present, for review, some of the equipments in the broad P.F.T. Line. Bulletins and catalogs on these and others not shown are available upon request.

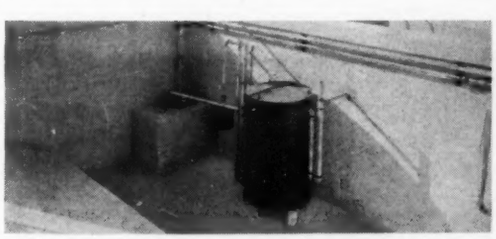


P.F.T. FLOATING COVER DIGESTERS

Hundreds of installations, including the largest in the world, prove the superiority of P.F.T. design. They effectively and positively control and accelerate the digestion process, eliminating odors and collecting gas for power purposes. Used in single and two-stage processes. Made in numerous sizes and shapes.

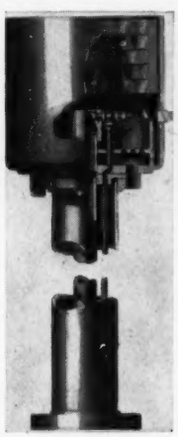
P.F.T. SPRINKLING FILTERS

Many communities of wide range of population are served by P.F.T. Sprinkling Filters which distribute sewage from the dosing tank onto the filter bed. Various types of P.F.T. Nozzles are available for varying conditions.



P.F.T. TWIN TANK CONTROLS

Perfected by P.F.T. engineers some years ago. Several hundred successful installations. They provide for effective dosing of common or separate field filter beds. Built with the same correctness of design, ruggedness and exactness characteristic of all P.F.T. Equipment.



P.F.T. WASTE GAS BURNERS

Simple, rugged, refractory-lined for long service. Fitted with pilot light. They burn off sewage gas safely from sewage plants; eliminate hazards.

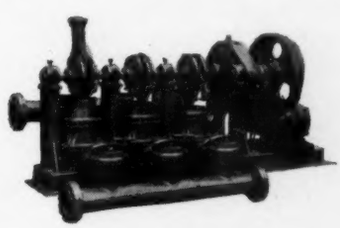
RELIEF WASTE GAS FLAME TRAP

They eliminate explosion hazards from digestion tank gases, eliminate water seals, reduce gas pressure losses.

Also P.F.T. Clarifiers, Type "B" Flame Traps, Dosing Tank and Flush Tank Counters, Jointite Sewer Pipe Joint Compound, etc.

P.F.T. ROTARY DISTRIBUTORS

Many installations, including the world's largest, are in operation today. They provide thorough distribution of sewage on filter beds. They feature the P.F.T. Patent Spreader Jet, unique bearing arrangement to withstand thrusts, and positive mercury seal.



P.F.T. SLUDGE PUMPS

Wear-resistant, non-clogging. Made in various sizes. Eccentrics are adjustable to control capacities. Ample bearings. Special rubber ball valves. Last for years in severe service.

P.F.T. ALTERNATING SIPHONS

Hundreds are in use on sand filter beds. For any number, size and arrangement of bed.

P.F.T *Pacific Flush-Tank Co.*

4241 RAVENSWOOD AVENUE, CHICAGO
NEW YORK CHARLOTTE, N.C. LOS ANGELES

SEWAGE TREATMENT EQUIPMENT EXCLUSIVELY SINCE 1893

WALLACE & TIERNAN CO., INC.

Manufacturers of Chlorine and Ammonia Control Apparatus
Dry Chemical Feed Devices, etc.
NEWARK, NEW JERSEY

"The Only Safe Sewage Is a Sterilized Sewage"

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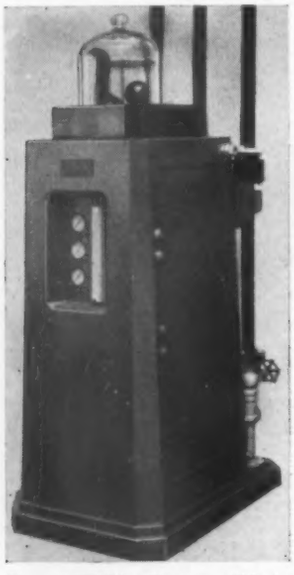
CHLORINATION OF SEWAGE

Of all chemicals used in sewage treatment, chlorine has by far the widest application. From simple disinfection to use as an adjunct to the most involved treatment process, chlorination has for many years been the versatile and valued aid of the man concerned with sewage disposal.

Chlorination is employed to stabilize raw sewage, control odors along trunk sewers or at treatment plants, protect masonry structures from disintegration, increase efficiency of filter beds and prevent filter ponding, improve sedimentation and remove settleable solids, improve sludge digestion, prevent bulking in activated sludge plants, reduce biochemical oxygen demand and retard putrefaction in the receiving water course, disinfect effluents before discharge and is a necessary adjunct to nearly any process of chemical precipitation.

DISINFECTION

Regardless of what the preliminary process of sewage treatment may be, disinfection of the effluent before discharge has come to be regarded as a necessity. Protection of water supplies, of bathing places and of shellfish propagation beds all require efficient disinfection. That chlorination offers the one practical and effective means of sewage disinfection today is universally acknowledged by sanitarians and public health authorities.



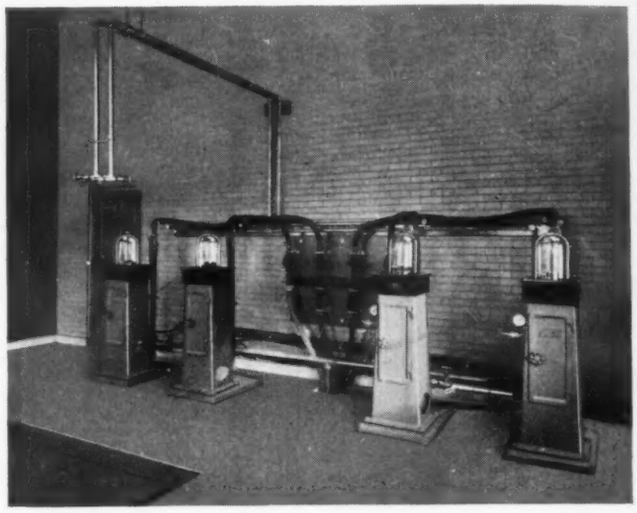
Master Visible Vacuum Chlorinator — W&T Visible Vacuum Control is now available in equipments ranging in capacity from .03 to 6000 pounds of chlorine per 24 hours.

ODOR CONTROL

Control of obnoxious odors from sewage treatment works, long outfall sewers and other disposal plant appurtenances is distinctly a field for chlorination. Neutralization of hydrogen sulphide (the gas responsible for these obnoxious odors) or prevention of its formation by controlled application of chlorine, is not only practical but also satisfactory in results and economy of operation.

B. O. D. REDUCTION

In order to prevent production of odor nuisance, foul appearance and death to fish life in streams receiving the effluents from sewage disposal plants, chlorination for B. O. D. reduction has become increasingly popular. Offering, as it does, a simple, easily controlled and relatively inexpensive means of supplementing other purification processes during periods of low stream flow or for permanent use at a plant where the dilution factor is low, chlorination has, in many cases, eliminated the necessity for extensive additions to the regular treatment works.



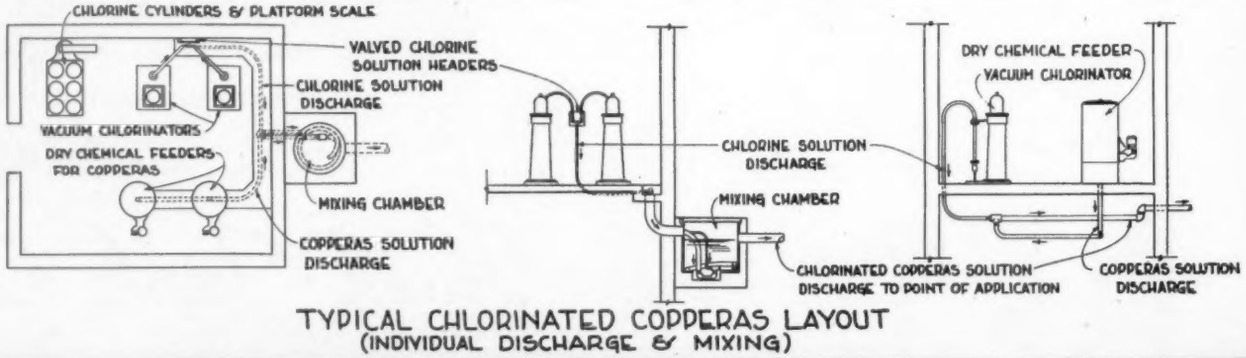
Installation of four Visible Vacuum Chlorinators at the New Haven, Conn., Sewage Disposal Plant.

IRON SALTS IN SEWAGE TREATMENT

Lowered cost of chemicals and other contributing factors have greatly increased the popularity of iron salts for various uses in sewage treatment, odor control, sludge conditioning, chemical precipitation, etc.

In whatever form this treatment may be adopted, such as the manufacture of ferric chloride at plant site, the addition of ferric chloride or of ferric sulphate directly, or the use of chlorinated copperas, W&T are prepared to furnished the necessary equipment. Complete details on request.

W&T field representatives will gladly confer with you about any specific problem relating to the application of chlorine or iron salts in sewage treatment. Technical publications and literature are available on request.



TYPICAL CHLORINATED COPPERAS LAYOUT
(INDIVIDUAL DISCHARGE & MIXING)

DEGREASING SEWAGE*

Experiences With the Aero-Chlorination Method

By GORDON J. WIEST

Chemist Sewage Treatment Works, Lancaster, Pa.

The separation of grease and oils from raw sewage is recognized as important to most sewage works operators, because the presence of these buoyancy producing materials in sewage lowers primary sedimentation efficiencies. Furthermore, they apparently interfere with efficient aeration and final clarification in the activated sludge process.

The method for degreasing sewage has been to aerate the sewage, utilizing air diffusion, for a short period as it flows through a channel or tank ahead of sedimentation tanks. This method has been practiced in a number of activated sludge type plants. The theory is that a violent diffusion of air bubbles sweeps the particles of grease and oils to the surface where coalescence and floatation results. The removal of the grease follows the pre-aeration and is effected by tank skimming by hand or with the aid of mechanical devices.

History

H. A. Faber, of the Chlorine Institute, in 1937 reported an improvement of this method of grease separation as a result of an experimental study conducted under his direction on a full plant scale at the Woonsocket, R. I., Sewage Treatment Works. Faber's method* was to admit gaseous chlorine into the air line serving the grease separation tank. This method of employing chlorinated air for grease separation has now come to be known as degreasing by "Aero-Chlorination." Faber reported an average chlorine dosage of 1.5 p.p.m. (based on sewage flows), with an average detention period of six minutes, increased the grease removal from 189% to 442% as compared to the use of aeration alone and employing the same quantity of air and contact period. The percentage increase in grease removal was based on pounds of wet grease (scum) removed per million gallons of sewage treated. Keefer and Cromwell, at Baltimore, Maryland, conducted similar experiments on a semi-plant scale at the Back River Sewage Treatment Works which results* confirmed Faber's findings at Woonsocket.

Lancaster Conditions

An investigation of the grease and oils present in the sewage at the South Plant in Lancaster, Pennsylvania, led me to believe that our difficulties could be minimized by attempting a method to increase the efficiency of our grease separation facilities. A laboratory investigation showed that grease and oils were present in the raw sewage delivered to the South Plant in rather variable and also comparatively high quantities. This laboratory investigation included a study of the grease content of the activated ("return") sludge. The "return sludge" at the South Plant averaged 21.63% (dry basis) grease, while the "return sludge" at the North Plant averaged but 5.0% grease. Briefly, Lancaster, Pennsylvania, has two sewage treatment plants—both being conventional activated sludge type design with separate sludge digestion. The North Plant was placed in operation in December, 1934, and has produced a high quality effluent with a minimum of difficulties. The South Plant, placed in operation in May, 1935, has since that time continuously offered a variety of problems which interfere with good operation.

The Lancaster Plants were designed for pre-aeration ahead of the primary sedimentation tanks. Screenings and grit are removed ahead of the pre-aeration channels. The pre-aeration channels are 6.5 feet in depth with diffuser plates on the bottom of the channels. The air delivered to these channels is measured and recorded in the Main Building. The grease removal after pre-aeration is effected by means of mechanical skimmers which carry the grease across the surface of the primary sedimentation tanks to the effluent end, where cross-skimmers remove the grease to collection pits. The grease is removed from the collection pits to the digestion tanks as required. The operation of the skimmers is not continuous; they are placed in operation for an average of five non-consecutive hours daily. The average detention period in the primary sedimentation tanks is 1.75 hours.

A Form of Aero-Chlorination Tried

The use of a form of Aero-Chlorination with hopes of improving grease separation was started at the South Plant under plant scale conditions in August, 1937. Chlorine in a gaseous

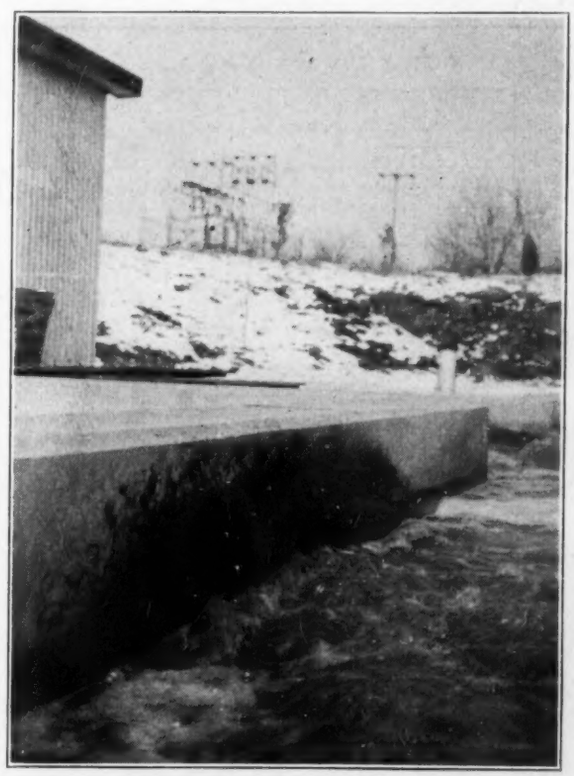
*See Ref. & Data Section—Apr., 1938, issue Water Works & Sewerage.

TABLE I
AERO-CHLORINATION VS. AERATION ALONE

Date (1937) August	Detention (minutes)	Air (Cu. Ft./Gal.)	Chlorine (p.p.m.)	Wet Grease lbs./M.G.
14	3.6	0.12	2.0	11.3
15	5.8	0.18	2.0	7.4
16	3.6	0.12	2.0	17.4
17	3.5	0.11	2.0	16.2
18	3.2	0.11	2.0	10.9
19	2.9	0.10	2.0	11.2
20	2.9	0.10	2.0	12.5
21	2.9	0.09	2.0	10.6
22	2.3	0.08	2.0	5.6
23	2.6	0.08	2.0	18.3
24	4.0	0.13	2.0	14.1
Average	3.4	0.11	2.0	12.3

Composite Samples: (Grease content)	Raw Sewage 25 p.p.m.	Primary Effluent 6.0 p.p.m.	% Removal* 76

Date (1937) August	Detention (minutes)	Air (Cu. Ft./Gal.)	Chlorine (p.p.m.)	Wet Grease lbs./M.G.
26	2.9	0.09	None	4.9
27	2.9	0.09	None	4.3
28	3.0	0.10	None	2.2
29	4.0	0.13	None	1.6
30	2.9	0.09	None	6.1
31	2.6	0.09	None	4.8
Average	3.1	0.10	None	4.0



Point of Chlorine Application
(Pre-aeration channel, with chlorinator house on left. Note the violent aeration at this point, for rapid and most effective distribution of small dosages of chlorine.)

Composite Samples: (Grease content)	Raw Sewage 19 p.p.m.	Primary Effluent 9.0 p.p.m.	% Removal† 53

*On the basis of pounds of wet grease removed, per million gallons of sewage treated, Aero-Chlorination increased the grease removal 308%.

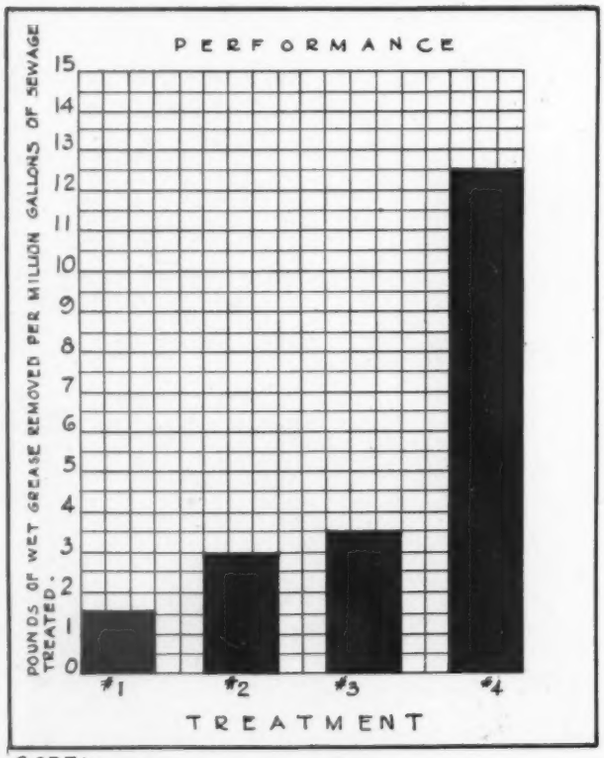
†On the basis of the analyses of raw sewage and primary effluent an increment of 23% is noted for the removal of grease using Aero-Chlorination over the use of aeration alone.

form could not be injected into the air line serving the pre-aeration channels. So, a W. & T. vacuum type solution feed chlorinator was set up to feed chlorine in solution directly to the raw sewage just ahead of air diffusion. The chlorine solution feed line was anchored in front of a baffle submerged directly ahead of the sewage delivery line. This insured thorough mixing. The dosing of the chlorine (as at Woonsocket and Baltimore[1-2]) has been calculated on the basis of raw sewage flow, for ease in interpretation and weighing of data—including costs of the procedure.

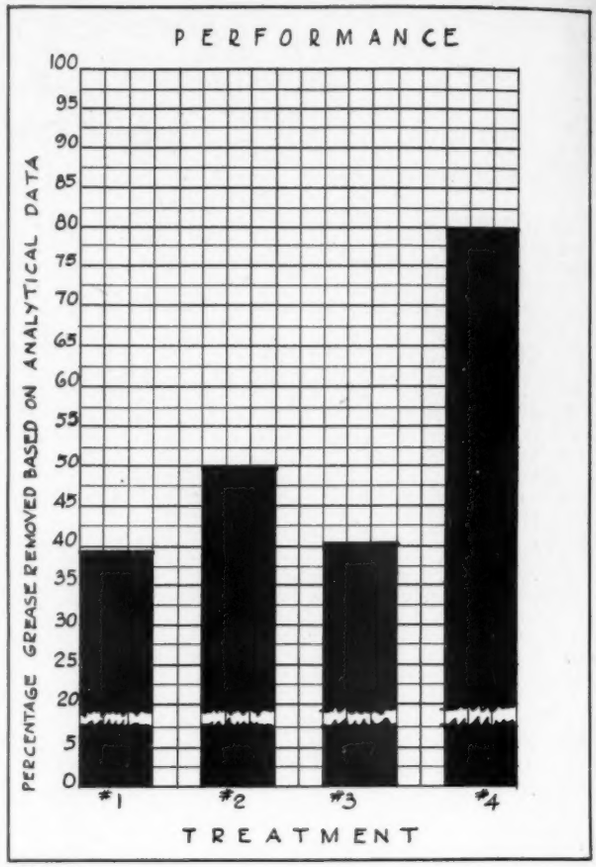
A number of preliminary tests were made alternating aeration alone with Aero-Chlorination—as we shall designate the procedure, even though not strictly Aero-Chlorination. Comparisons were made from the appearance of the grease collecting on the surface of the primary sedimentation tanks. Aero-Chlorination invariably produced more grease on the primary tanks than aeration alone. Variable dosages of chlorine were applied to the sewage mixed with air and it was found that chlorine was lost when applied in excess of 3.0 p.p.m. (This gives some indication of how closely the air blowing followed the chlorine application.) An average of only 2.0 p.p.m. has been applied throughout the experimental measurements, to avoid possible loss of chlorine, and also because preliminary results indicated that a dosage of 2.0 p.p.m. was effective for the treatment desired.

Analytical Procedure

The performance of Aero-Chlorination, under plant scale conditions, was measured during defined experimental periods by determining the grease content of the raw sewage ahead of pre-aeration and of the effluent from the primary sedimentation tanks. The percentage grease removal was computed from the analytical results. The grease content of the raw sludge was also determined and the total grease removed computed. The method for



CODE:
#1. TREATMENT WITHOUT AERATION AND WITHOUT CHLORINE.
#2. AERATION ALONE.
#3. CHLORINATION ALONE.
#4. AERO-CHLORINATION.



CODE:
#1. TREATMENT WITHOUT AERATION AND WITHOUT CHLORINE.
#2. AERATION ALONE.
#3. CHLORINATION ALONE.
#4. AERO-CHLORINATION.

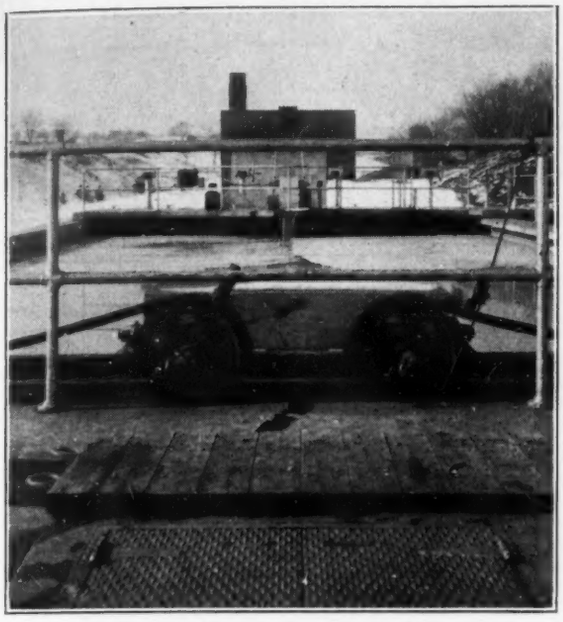
the grease determinations followed Standard Methods of Water & Sewage Analysis (A.P.H.A.). The grease extractions were made, using petroleum ether throughout the experimental measurements reported. The grease was removed from the collection pits daily during experimental measurements and the weight was recorded after draining for not less than one hour. The weight of the grease was reported on a wet basis as pounds of wet grease removed per million gallons of sewage treated. The performance of Aero-Chlorination was compared with aeration alone, then without aeration or chlorination, and then chlorination alone. The grease content of the activated ("return") sludge was reported from time to time, since it is felt that the grease content of the "return sludge" may determine the efficiency of the activated sludge during aeration of the sewage sludge mixtures.

Results

Aero-Clorination Alone

Experimental measurements were made from August 14th to 24th, 1937, using Aero-Chlorination. The chlorine dosage was 2.0 p.p.m. The experimental measurements continued from August 26th to 31st, 1937, using aeration alone. The results are shown in Table I. On the basis of the weighed pounds of wet grease removed per million gallons of sewage treated, Aero-Chlorination increased the grease removal 308% (see table) over the treatment using aeration alone. Laboratory analytical results showed a grease removal of 76%, using Aero-Chlorination and a grease removal of 53%, using aeration alone.

These experimental measurements were repeated from September 5th to 15th, using Aero-Chlorination and comparative tests were made September 20th to 30th, using aeration alone. The chlorine dosage was 2.0 p.p.m. The results appear in Table II. On the basis of pounds of wet grease removed per million gallons of sewage treated, Aero-Chlorination increased the grease removal 373% over the treatment using aeration alone. Laboratory analytical results showed a grease removal of 78%, using Aero-Chlorination, and a grease removal of 63%, using aeration alone.



Primary Sedimentation Units
(Note the surfaces covered with liberated grease which the skimming mechanism removes.)

Controlled Check Tests—3 Methods

In February, 1938, due to the interruption of plant operations caused by the presence of excessive quantities of gas wastes in the sewage; it was possible to maintain fairly constant operating conditions over a period of time for experimental observations of the performance of Aero-Chlorination. The sewage flow was maintained at 4.0 M.G.D., giving a constant value for detention period and air applied. Chlorine was applied at 2.0 p.p.m. A five-day test was made February 17th to 21st, using treatment without pre-aeration and without chlorine. Another five-day test was made March 4th to 9th, using pre-aeration treatment alone. A third test was made March 16th to 21st, using Aero-Chlorination. The results of these measurements under rather constant conditions are shown in Table III. On the basis of pounds of wet grease removed per million gallons of sewage treated, aeration *alone* increased grease removal 187% over the treatment without aeration and without chlorine; Aero-Chlorination increased the grease removal over aeration alone by 417%; and Aero-Chlorination increased the grease removal 781% over the treatment without aeration and without chlorine. Laboratory analytical results showed 38% grease removal, using treatment without aeration and without chlorine; 50% grease removal, using aeration alone; and 80% grease removal, using Aero-Chlorination.

CUT —— —— .... ——

Fig. 1

CUT —— —— .... ——

Fig. 2

The grease determinations on the raw sludge and the scum removed are reported for these experimental periods in Table IV.

Chlorination Alone

Experimental measurements were made, using chlorination alone for grease separation on three successive Mondays and three successive Wednesdays during July, 1938. These measurements were made at the suggestion of H. A. Faber of the Chlorine Institute. The results appear in Tables V, VI, and VII. Mondays and Wednesdays were the days selected for these measurements because experience showed that the raw sewage has a maximum grease content on Mondays and an average grease content on Wednesdays. The chlorine dosages were 2.0 p.p.m. The experimental conditions as to the dosing of chlorine and plant operation were parallel to the experimental conditions during the previous measurement periods, using Aero-Chlorination, aeration alone, and the treatment without aeration and without chlorine. The appearance of the grease collecting on the primary tanks were visibly present in smaller quantities than during the treatment using Aero-Chlorination. On the basis of pounds of wet grease removed per million gallons of sewage treated, chlorination *alone* increased the grease removal 219% over the treatment without aeration and without chlorine; and chlorination *alone* increased the grease removal 117% over the treatment using aeration *alone*. However, Aero-Chlorination increased the grease removal 371% over the treatment with chlorination alone. These comparisons are made, using the average of the results reported in July, 1938, and the results reported in February and March, 1938. The analytical results showed chlorination alone removed 41% of the grease. The grease analyses of the raw sludge and the grease collected are reported in Table VII.

TABLE II
AERO-CHLORINATION VS. AERATION ALONE

Date (1937) Sept.	Detention (minutes)	Air (Cu. Ft./Gal.)	Chlorine (p.p.m.)	Wet Grease lbs./M.G.
5	3.1	0.09	2.0	6.5
6	3.5	0.11	2.0	15.7
7	2.9	0.10	2.0	17.1
8	2.9	0.10	2.0	12.4
9	2.9	0.10	2.0	16.8
10	3.5	0.11	2.0	18.5
11	4.1	0.13	2.0	11.4
12	4.3	0.14	2.0	5.9
13	3.9	0.12	2.0	18.0
14	4.3	0.13	2.0	14.5
15	5.8	0.18	2.0	15.2
Average	3.7	0.12	2.0	13.8

Composite Samples:	Raw Sewage	Primary Effluent	% Removal*
(Grease content)	23 p.p.m.	5.0 p.p.m.	78

Date (1937) Sept.	Detention (minutes)	Air (Cu. Ft./Gal.)	Chlorine (p.p.m.)	Wet Grease lbs./M.G.
20	3.8	0.12	None	4.3
21	3.5	0.11	None	3.4
22	3.5	0.11	None	4.1
23	3.9	0.12	None	2.6
24	3.3	0.10	None	3.5
25	3.2	0.10	None	4.3
26	3.9	0.12	None	2.8
27	3.4	0.10	None	5.7
28	3.4	0.10	None	3.8
29	3.4	0.10	None	2.3
30	3.4	0.10	None	4.4
Average	3.5	0.11	None	3.7

Composite Samples:	Raw Sewage	Primary Effluent	% Removal†
(Grease content)	27 p.p.m.	10.0 p.p.m.	63

*On the basis of pounds of wet grease removed, per million gallons of sewage treated, Aero-Chlorination increased the grease removal 373%.

†On the basis of the analyses of raw sewage and primary effluent an increment of 15% is noted for the removal of grease using Aero-Chlorination over the use of aeration alone.

TABLE III
THREE METHODS COMPARED

Date (1938) February	Detention (minutes)	Air (Cu. Ft./Gal.)	Chlorine (p.p.m.)	Wet Grease lbs./M.G.
17 (Thursday)	4.3	None	None	1.3
18 (Friday)	4.3	None	None	1.9
19 (Saturday)	4.3	None	None	0.9
20 (Sunday)	4.3	None	None	2.1
21 (Monday)	4.3	None	None	1.6
Average	4.3	None	None	1.6

Composite Samples:	Raw Sewage	Primary Effluent	% Removal*
(Grease content)	21 p.p.m.	13.0 p.p.m.	38

Date (1938) March	Detention (minutes)	Air (Cu. Ft./Gal.)	Chlorine (p.p.m.)	Wet Grease lbs./M.G.
4 (Friday)	4.3	0.14	None	3.1
5 (Saturday)	4.3	0.14	None	2.9
6 (Sunday)	4.3	0.14	None	2.6

7 (Monday)	4.3	0.14	None	2.0
8 (Tuesday)	4.3	0.14	None	3.1
9 (Wednesday)	4.3	0.14	None	4.4
Average	4.3	0.14	None	3.0

Composite Samples:	Raw Sewage	Primary Effluent	% Removal*
(Grease content)	26 p.p.m.	13.0 p.p.m.	50

Date (1938) March	Detention (minutes)	Air (Cu. Ft./Gal.)	Chlorine (p.p.m.)	Wet Grease lbs./M.G.
16 (Wednesday)	4.3	0.14	2.0	10.4
17 (Thursday)	4.3	0.14	2.0	13.2
18 (Friday)	4.3	0.14	2.0	12.9
19 (Saturday)	4.3	0.14	2.0	15.3
20 (Sunday)	4.3	0.14	2.0	7.5
21 (Monday)	4.3	0.14	2.0	15.7
Average	4.3	0.14	2.0	12.5

Composite Samples:	Raw Sewage	Primary Effluent	% Removal*
(Grease content)	21 p.p.m.	4.0 p.p.m.	80

*On the basis of pounds of wet grease removed, per million gallons of sewage treated, aeration increased the grease removal 187%. Aero-Chlorination increased grease removal over aeration alone 417%. Aero-Chlorination increased grease removal 781% over the treatment without aeration and without chlorine.

*On the basis of analyses of raw sewage and primary effluent an increment of 12% is noted for the removal of grease using aeration, over the treatment without aeration and without chlorine. An increment of 30% is noted using Aero-Chlorination over aeration alone. An increment of 42% is noted, using Aero-Chlorination over the treatment without aeration and without chlorine.

TABLE IV

GREASE CONTENT OF PRIMARY SLUDGE AND SCUM

Date 1937—	Treatment	Raw Sludge Pct.	Scum Pits Pct.
Aug. 14-24	Aero-chlorination	27.56*	14.65*
Aug. 26-31	Aeration alone	32.08	12.69
Sept. 5-15	Aero-chlorination	25.67	16.34
Sept. 20-30	Aeration alone	31.17	14.19
1938—			
Feb. 17-21	Without aeration and without chlorine	31.19	10.17
March 4- 9	Aeration alone	30.08	11.19
March 16-21	Aero-chlorination	26.68	12.87

*Grease as determined by Standard Methods of Analysis—A.P.H.A.

TABLE V

PRE-CHLORINATION ALONE

Date (1938) July	Detention (minutes)	Air (Cu. Ft./Gal.)	Chlorine (p.p.m.)	Wet Grease lbs./M.G.
11 (Monday)	4.1	None	2.0	2.7
13 (Wednesday)	3.7	None	2.0	1.9
18 (Monday)	3.4	None	2.0	4.7
20 (Wednesday)	3.4	None	2.0	3.1
25 (Monday)	3.4	None	2.0	4.8
27 (Wednesday)	2.9	None	2.0	4.0
Average	3.5	None	2.0	3.5*
Maximum	4.1	None	2.0	4.8
Minimum	2.9	None	2.0	1.9

*On the basis of pounds of wet grease removed, per million gallons of sewage treated, the treatment using chlorination alone increased the grease removal 219% over the treatment without aeration and without chlorine. The treatment using chlorination alone increased the grease removal 117% over the treatment using aeration alone. These comparisons are made using the average of the results reported in July, 1938, and the results reported in February and March, 1938.

TABLE VI

PRE-CHLORINATION ALONE

(Grease Content in p.p.m.*)

Date (1938) July	Raw Sewage	Primary Effluent	% Grease Removal
11	16	11	31
13	12	7	41
18	21	13	38
20	18	10	44
25	23	11	52
27	17	10	41
Average	18	10	41
Maximum	23	13	52
Minimum	12	7	31

*By Standard Methods of Analysis—A.P.H.A.

TABLE VII

PRE-CHLORINATION ALONE

(Grease Content—Dry Basis*)

Date (1938) July	Raw Sludge Pct.	Scum Pits Pct.
11	31.63	13.09
13	28.65	12.39
18	35.09	15.37
20	36.11	14.29
25	34.61	14.86
27	33.96	15.10

*By Standard Methods of Analysis—A.P.H.A.

TABLE VIII

QUALITY OF ACTIVATED ("RETURN") SLUDGE

Date	April (1937)	May (1938)	July (1938)	August (1938)
Per cent grease*	21.63	7.78†	6.56†	5.61†
Per cent total solids	0.82	1.02	1.54	1.42
Per cent volatile solids	74.21	77.74	79.32	79.67

*Petroleum ether extraction by Standard Methods.

†Percentage reduction of grease content of Activated ("Return") Sludge:

	Pct.
April, 1937, to May, 1938	64
April, 1937, to July, 1938	70
April, 1937, to August, 1938	74

Improvement in Activated Sludge Noted

The grease content of the activated ("return") sludge has been determined at frequent intervals since Aero-Chlorination has been in use. The grease content of the "return sludge" at the South Plant has been reduced between 64% and 74%. To our mind, this improvement has been due to Aero-Chlorination. These results are shown in Table VIII.

Discussion and Summary

The grease content of "return sludge" may determine the efficiency of the aeration of sewage sludge mixtures. It is believed that the presence of grease and oils in the "return sludge" and the sewage sludge mixtures do not permit the balancing of rate of oxygen utilization, because the grease and oils spread a protective film on the sewage and sludge particles, making intimate contact, and resulting oxidation slow and incomplete. Also, the absorption of the colloidal matter present in the sewage by the "return sludge" is not complete in the presence of grease and oils, because of this protective film. Aero-Chlorination of the raw sewage for grease removal does reduce the grease content of the sewage and sewage sludge mixtures to a marked degree; thereby, bringing the rate of oxygen utilization into a proper balance. The results at Lancaster show that Aero-Chlorination reduced the grease content of the raw sewage to the extent of 80%.

As the result of our tests and study of benefits derived, Aero-Chlorination has been made an operating feature at both of the sewage treatment plants of Lancaster. Since introducing Aero-Chlorination, the South Plant in Lancaster has experienced its first six months of continuously successful operation of the activated sludge phase of treatment. A high quality effluent has

been consistently produced for the past six months, with a continuous and pleasing absence of "bulking" troubles.

Acknowledgment is made to L. H. Enslow and H. A. Faber of Chlorine Institute for their helpful suggestions and guidance.

The Department of Streets and Public Improvements is responsible for the management of the Lancaster Sewage Treatment Works. J. A. Taylor, Director; J. H. Shertzer, City Engineer; and E. J. Rhoads, Superintendent.

[The text of this article was presented, in a large measure, before the Pennsylvania Sewage Works Association, as the author's contribution to the "Clinic" held annually in diagnosing or solving problems of the operator. It has since been redrafted and amplified for publication in "Water Works and Sewerage." —Ed.]

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[1]H. A. Faber, Water Works & Sewerage, 84, 171 (1937).
[2]Keefer & Cromwell, Water Works & Sewerage, 85, 97 (1938).

CONTROL OF ACTIVATED SLUDGE BULKING*

Experience With Partial Chlorination

By E. E. SMITH, Superintendent
Water Works and Sewerage, Lima, Ohio

The operation of the Activated Sludge type of sewage treatment plant has the ever present danger of the so-called sludge bulking. Sewage literature abounds with descriptions, reasons for and treatment of this phenomenon. Experiences at the Lima Sewage Treatment Works seems to indicate close correlation between a marked increase in the numbers of bacterial filaments in the aeration units and poor settling of sludge in the final settling tanks, decrease in dissolved oxygen in final tanks, and poor clarification of final effluent. Sludge bulking seems to be the common cause of inefficient and uneconomical operation of activated sludge plants.

During the summer of 1934 when sludge bulking occurred, all previously described remedies were employed. The sewage upon which these remedies were tried was, in common to most sewages of that drought period, unusually strong and high in temperature, with the consequent necessity of efficient purification during the low stream flows.

Experimentation with Chlorine

Sanitary Engineer J. K. Hoskins of the United States Public Health Service had mentioned to the writer some beneficial results to the process following the use of chlorine at the Stream Pollution Investigations Experimental Plant, in Cincinnati. It was decided, therefore, to look into the effects of chlorine gas on the returned activated sludge.

The design of the Lime Sewage Treatment Works was admirably adapted for this particular experiment for the following reasons:

Activated sludge from the final tanks is brought through two separate 12 inch sludge lines from the tank sumps to a sight feed hopper where separate sludge valves control the sludge flow into a 14 inch combined gravity line conveying the sludge 95 ft. to the returned sludge sump. For purposes of chlorination this arrangement permits *good mixing* and a contact period of ten to twenty minutes, depending on the rate of sludge returned. The results obtained from the use of one tank of chlorine, applied without careful control, were so evidently desirable, that arrangements were made for use of W. & T. solution feed chlorinator.

Observations during the treatment of the returned sludge revealed that seven days after the start of chlorination filaments were absent from the sludge. The ratio of *p.p.m. chlorine to each per cent of solids in the returned sludge* is apparently a governing factor in the action of filament removal, because results were not being obtained when that ratio was below 1.00 during the second application of chlorine. No filament removal was noted for the twelve days of low ratio chlorine dosage.

Inasmuch as the last eleven days of application of chlorine during the first experiment and the first twelve days of the second experiment seemed to indicate that chlorine applied below the apparent threshold ratio of 1.00 was without sufficient effect, a further experiment with chlorine was made at ratios of 2.00 or more.

At the Lima Sewage Treatment Works daily microscopical examinations of the aeration tank effluent are made, as well as the usual hourly estimations of percentage of settling solids in the aeration tank effluent. From the indications of these two determinations the chlorine produced a marked reduction of the excessive numbers of filaments. Their complete removal was not attempted, nor did it seem necessary.

Economy of the Process

Air requirements have been reduced to little more than the delivery of the smallest size blower, without regard to variations in sewage flow. It may be estimated that air requirements, without the danger of bulking, should not exceed an average of 0.90 cu. ft. per gallon of sewage. As bulking could be expected usually when the air-sewage ratio was reduced below 1.00 to 1.25 cu. ft. per gallon, the ability to use chlorine as above indicated resulted in a net saving.

The application of air has been as low as 0.62 cu. ft. per gal. daily average and as low as 0.78 monthly average during chlorination. Without the ability to correct sludge bulking so readily and effectively with chlorine such low applications of air would have been unwise and impracticable.

[*Excerpts from an article which appeared in WATER WORKS AND SEWERAGE, October, 1935, here reproduced because other plants have subsequently found the Lima scheme of mild chlorination of returned sludge beneficial in holding oxygen in the aeration units and maintaining performance of the activated sludge process on a more even keel in difficult operating periods. Since 1934 chlorination at Lima has continued to yield beneficial effects.—ED.]

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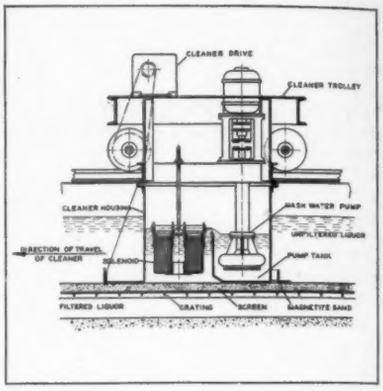
LEFT: One of three Automatic Magnetite Filters installed in combination with Dorr Clarifiers at Dearborn, Mich.

RIGHT: Section through cleaner of a combination unit.



THE AUTOMATIC MAGNETITE FILTER

The magnetite filter is an automatic strainer for the removal of suspended solids from sewage effluents of primary and secondary settling tanks—also for treating domestic and industrial water supplies. Two types are available—the upward and the downward flow types—both of which may be installed either as integral parts of circular or rectangular settling tanks or else in separate circular or rectangular structures, following primary and secondary sedimentation.

CONSTRUCTION

The filter medium is a three-inch layer of carefully sized magnetite iron ore, supported by a non-corrosive screen. Washing of the medium is effected by a solenoid, alternately magnetized and demagnetized, which periodically lifts and releases a narrow strip of magnetite. Thus the fine sewage solids, caught between the grains, are released and washed over into a separate compartment and thence pumped back to process or other disposal. Fine or coarse magnetite may be used, depending on local conditions.

APPLICATIONS OF AUTOMATIC MAGNETITE FILTERS

In general, the use of Automatic Magnetite Filters results in uniformly good effluents, regardless of variations in the volume and character of the influent, thus helping to eliminate secondary sludge depositions in receiving bodies of water. The cost per ton of solids removed is less than for any other method operating in the same range of treatment.

- **Plain Sedimentation**—Less settling capacity is required and effluent is improved 40%. Settling for 2 hours plus magnetite filtration yields 80% removal suspended solids. 15-25% less chlorine required for filtered than for unfiltered effluents.
- **Chemical Precipitation**—A 50% reduction in chemical consumption, less time for coagulation and settling and a better final effluent.
- **Activated Sludge**—Less settling and aeration tank capacities, less compressed air and a better final effluent. Safeguards plant against operating irregularities.
- **Trickling Filters**—Less primary settling tanks and less suspended solids to handle, if installed ahead of filters. Less humus tank capacity, less final unsettleable solids and a better final effluent, if installed after filters.
- **Water Treatment**—Removes algae from raw, untreated water and clarifies chemically-treated and settled water.

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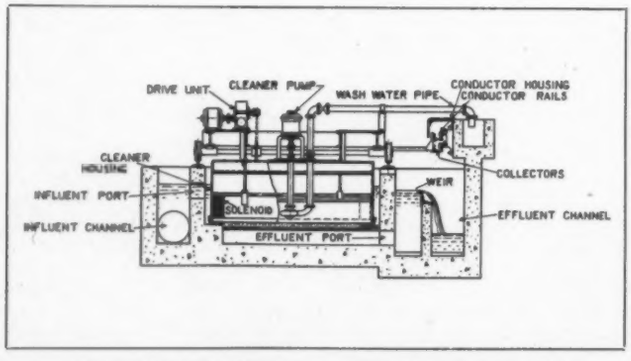
These filters are used for dewatering raw and digested sludges—plain settled, chemically-precipitated and activated.



Section through cleaner of a separate structure unit.

Three Automatic Magnetic Filters installed in separate structures at Cleveland, Ohio.

OPERATING CONTROL TESTS FOR THE ACTIVATED SLUDGE PROCESS*

By T. R. HASELTINE†

Superintendent of Sewerage, Butler, Pa.

The first requirement of the activated sludge process is the maintenance of dissolved oxygen in the aeration tanks. As early as 1926, Harris, Cockburn and Anderson[1] stated this principle of the process very clearly. Their work proved that "the dissolved oxygen adsorbed by the sludge is a constantly decreasing amount from its contact with the inflowing sewage to its discharge from the reactivation channels. The *starting point* of the process of reactivation may be accepted as the point nearest the inflow of the aeration tank at which dissolved oxygen first appears. The degree of reactivation that takes place in the aeration tank is dependent upon the balance maintained between the supply of, and the demand on, the dissolved oxygen and the period of detention as timed from the determined starting point."

Every operator of an activated sludge plant must know that the process is dependent upon aerobic bacterial action. Therefore, it should be evident to all that the presence of dissolved oxygen in the aeration tanks is a prime requisite for the proper functioning of the process. In spite of its self-evident nature some operators may lose sight of this principle of the process, due perhaps to their efforts to comprehend and apply the never-ending stream of articles dealing with the relative merits of pH control, various types and designs of structures and equipment, or the use of chemicals as an adjunct to the process. It is, therefore, very refreshing to read Mr. Anderson's timely and extremely logical articles[2, 3, 4] on the operation and control of the Rockville Center activated sludge plant. It was those articles that led the writer to prepare the following discussion for publication in WATER WORKS AND SEWERAGE that carried Mr. Anderson's two articles.

"Tapered Aeration"

The "tapered aeration" effect while not new in principle, is worthy of far more widespread application than it now receives. The writer operated the Salinas, California, plant[5] from 1930 to 1933. During that time we found, after extensive experimentation, that the best results were obtained by so adjusting the air distribution that (a) there was an appreciable amount of dissolved oxygen in the sludge reaeration compartments, (b) there was at least a small amount at the inlet of the aeration compartments, and (c) the dissolved oxygen gradually increased towards the outlet of the aeration compartments. This required the use of from 55 to 70 per cent of the total air applied in the first half of the aeration tanks. The percentage increased some with high sewage flows, low air supplies, or bulked sludge and visa versa.

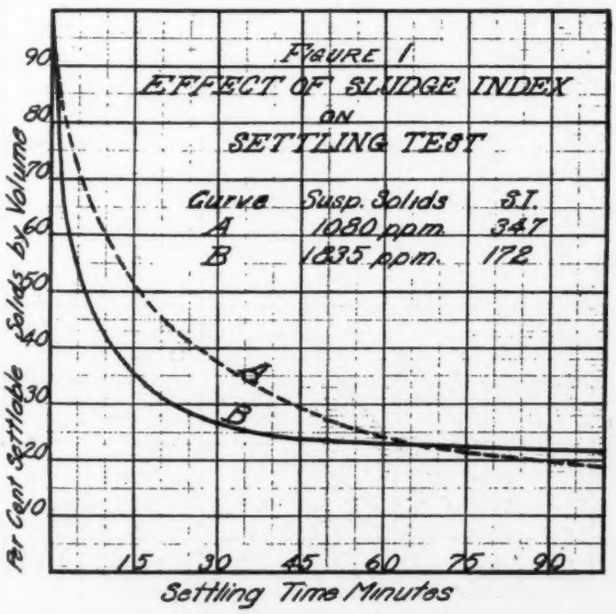


Fig. 1.—The Effect of Sludge Density (Sludge Index) on the Volumetric Sludge Settling Test.

Dissolved Oxygen Tests

To maintain "tapered aeration" it is, as Mr. Anderson points out, necessary to make frequent dissolved oxygen (D.O.) determinations throughout the aeration tanks. However, the writer marvels at the success of Mr. Anderson[4] in using the regular Winkler method for such determinations; first, because one would expect interference from nitrites and, second, because it has been our experience that the sludge floc adsorbed some of the reagents and masked the end point of the titrations. We doubt if the operators of many activated sludge plants would find the regular Winkler method satisfactory. The Report of the Committee on Methods of Sewage Analysis[6] states that "as a rule nitrites will occasion erroneously high results when present in amounts exceeding 0.1 p.p.m. of N. as nitrite. Interference due to nitrites may be expected in dealing with effluents from biological oxidation devices." Whenever the presence of nitrites is suspected the report recommends the use of the permanganate modification of the Winkler method. At Salinas our crude sewage had an organic-plus ammonia nitrogen content of about 65 p.p.m. Our final effluent usually contained from 0.2 to 3.0 p.p.m. of nitrite nitrogen. As might be expected we found the regular Winkler method valueless under such conditions; in fact, we had to use a double strength permanganate solution much of the time.

The accurate determination of the dissolved oxygen in the mixed liquor of the aerators is extremely difficult and requires special apparatus such as was devised by Theriault and McNamee.[7] They state that the usual technique of working only on supernatant liquor from settled sludge gives low results (not subject to empirical correction) due to the high oxygen demand of the sludge itself. However, the writer believes that with proper care it is entirely permissible (for routine plant control) to work on a supernatant liquor and thus avoid the complications of sludge floc or the use of special equipment. It is always desirable to have a margin of safety in plant operation and the errors pointed out by Theriault and McNamee are on the side of safety.

At Salinas we collected samples of mixed liquor from various points throughout the aerators in 2 liter bottles. The bottles were completely filled, stoppered and allowed to stand until 270 m.l. of fairly clear supernatant liquor could be siphoned off into small bottles. The permanganate modification of the Winkler method was then used to determine the dissolved oxygen content of these smaller samples. Ordinarily 5 to 15 minutes' standing of the 2 liter samples would result in sufficient clarification although at times of severe bulking as much as 40 minutes elapsed before the small samples could be siphoned off. On several occasions we siphoned off a second small sample an hour or two after taking the first one and repeated the D.O. determinations. The decrease in dissolved oxygen in the supernatant over the elapsed time was surprisingly small even though the liquor had been underlain by sludge all that time.

Second Operating Requirement

The necessity of maintaining an adequate supply of dissolved oxygen in the aerators at all times, when coupled with the desirability of keeping the power expenditure for aeration at a minimum, leads directly to the second operating requirement—namely, that of keeping the oxygen demand of the mixed liquor at a minimum. The oxygen demand of the mixed liquor is in part due to that of the sewage and in part due to that of the sludge. However, that of the sludge is so much the greater, that of the sewage becomes almost negligible. Grant, Hurwitz and Mohlman[8] proved in the laboratory that (a) mixtures of sewage plus sludge absorb oxygen in proportion to the weight of sludge but with increasing amounts of sludge most of the oxygen demanding material of the sewage is coagulated or adsorbed by the sludge so that very little oxygen is required for the unadsorbed material, and (b) small amounts of sludge reduce the B.O.D. of the sewage almost as rapidly as do larger amounts. Their findings have since been proven in many full scale plants.

It is, therefore, the problem of the operator to first determine

*From WATER WORKS AND SEWERAGE.

†With Chas. A. Haskins, Consulting Engineer, Kansas City, Mo., when this article was prepared.

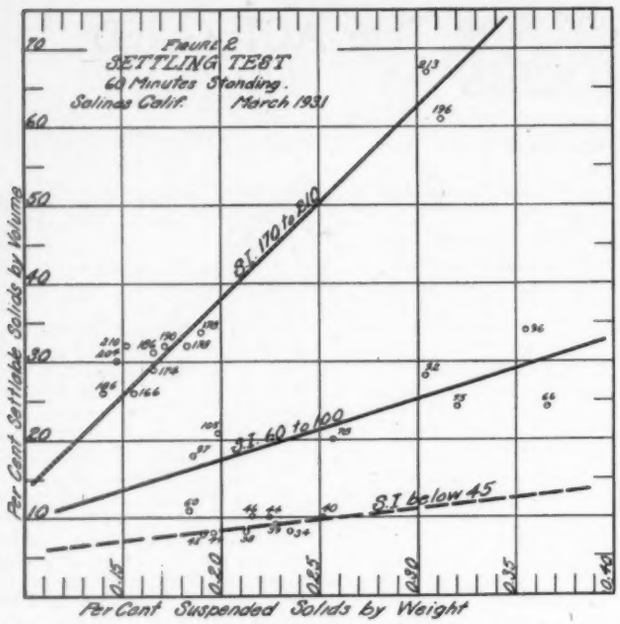


Fig. 2.—A Picture of the Lack of Correlation Between Volumetric Sludge Test and the Gravimetric Test. The Necessity of Taking into Consideration the Density and Settleability (Sludge Index) Is Clearly Evident.

the minimum *weight* of sludge that it is necessary to carry in his own individual plant and then, second, to so control the rate of sludge return that that minimum amount is never greatly exceeded. To solve that problem it would be desirable to have some rapid and accurate means of approximating the *weight* of solids in a given volume of mixed liquor or return activated sludge. As yet no universally satisfactory method of making this determination has been devised. Three methods that have been more or less generally used are (a) settling tests, (b) suspended solids determinations, and (c) centrifugal tests.

All have their disadvantages.

Settling Tests

These are the simplest tests and were the earliest tests used. Samples of sludge or mixed liquor are simply collected in liter graduates, allowed to stand for some given time, and the per cent of settleable solids observed at the end of the given time. In the early days it was usually customary to carry about 20 per cent sludge, after 30 minutes standing, in the mixed liquor. The test is still used and is quite helpful so long as its limitations are kept in mind. Various standing times are used ranging from 10 minutes to 1 hour.

Attempts to correlate the volume of settleable solids, as determined in this way, with the actual weight of the suspended solids in the sample soon showed that no such relationship existed unless the sludge index[5] was also taken into consideration, see Figure 2. "The sludge index (S.I.) is the volume in cubic centimeters occupied by 1 gram of sludge solids after settling 30 minutes." The longer the settling test samples are allowed to stand, i.e., the more the sludge compacts, the less the influence of the S.I. on the results of the test and hence the closer their approximation to the actual weight of sludge solids present. Figure 1 illustrates this point fairly well. However, the rate of sewage inflow to the aeration tanks is constantly changing and tests to regulate the amount of return sludge must be rapid if the weight of sludge solids returned is to be varied in accordance with the sewage flow.

In general the settling test alone can not be relied on except in the smallest plants, and even then only in those small plants that are so amply designed that they are subject to little bulking. In such plants the possible saving in power may not be great enough to warrant the added cost of conducting more accurate test methods.

Suspended Solids Determinations

Suspended solids determinations are the only accurate means of determining the actual *weight* of sludge solids in a given sample of mixed liquor or return sludge. Unfortunately so much time is required for making the determinations that the test is useless as a means of coordinating the hourly rates of addition of sludge solids with the hourly rates of sewage inflow to the aerators. In spite of this handicap the test is extremely valuable and should be made at least once a day at all but the very smallest plants. It should be made at the same time each day; the time selected should be such that the sewage flow for the past several hours has been nearly identical with that of the same hours of each preceding day.

For example, at Salinas[6] we took samples for suspended solids determinations each day at 9 a. m., there being only slight day to day variations in the hourly rates of flow received at that plant between 2 a. m. and 9 a. m. We governed the daily amount of activated sludge wasted almost entirely by the results of these determinations. (The rate of sludge withdrawal from the clarifiers was governed by hourly determinations of the depth of sludge in them. We attempted to keep the rate of withdrawal as low as possible without permitting more than a 1-foot depth of sludge at the sides of the Dorr tanks.) This procedure did *not* accomplish the very desirable end of keeping the suspended solid content of the aerators constant at all times throughout the day. It was probably at a minimum about 11 a. m. when the peak flow started coming in and at a maximum between 10 and 11 p. m. when the flow started dropping off rapidly. However, it did serve to keep the *average daily* suspended solid content of the aerators fairly constant.

Before leaving the subject of gravimetric solids determinations the writer wishes to make a plea for all operators to base their control on *suspended* solids determinations rather than on *total* solids determinations. It is the suspended solids in the sludge that exert the bulk of its oxygen demand. It would be permissible to base plant control on total solids determinations only if the dissolved solids were practically constant. Such is not the case—at Salinas,[6] dissolved solids in the mixed liquor, and plant effluent, ranged from 600 to 1500 p.p.m. under varying sludge conditions.

Centrifugal Tests

This test consists of collecting samples of mixed liquor or sludge in 15 m.l. centrifuge tubes and "spinning" them for a given short time (2 to 5 minutes) in an electrical centrifuge. A hand centrifuge will not serve because of the impossibility of always spinning the samples at the same speed. The writer first heard of this test being used at the Indianapolis plant some eight or nine years ago. We tried it for several months at Salinas. Mr. Anderson[2, 3, 4] has recently reported its successful use at Rockville Center. The test has probably been used at several other plants but it has never been widely adopted. To the writer's knowledge, Mr. Anderson is the first to mention it in the literature.

Like the settling test, the centrifugal test is at best volumetric determination. Nevertheless, it has two outstanding advantages over the gravity settling test. (a) It is extremely rapid and so

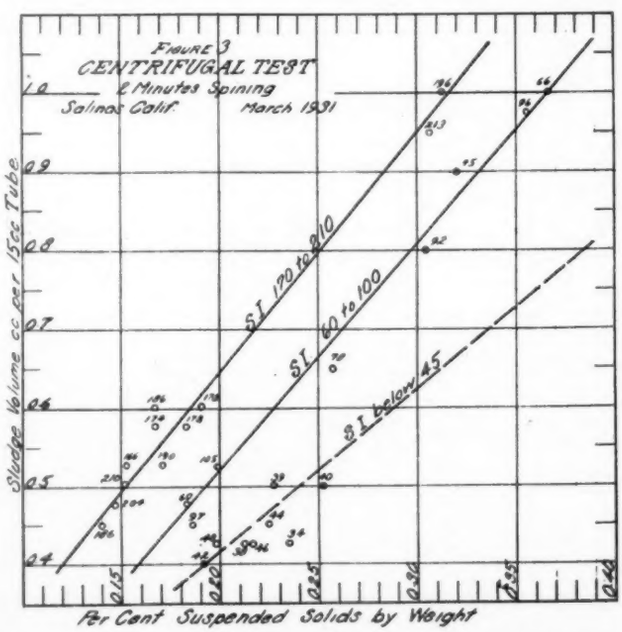


Fig. 3.—A Picture of the Less but Evident Effect of Sludge Index Values on Suspended Solids Tests With the Centrifuge.

may be utilized, with reservations, to control the hourly rates of sludge withdrawal or return. (b) It compacts the suspended solids more and hence there is better correlation between its results and those of gravimetric suspended solids determinations. However, even the results of this test are greatly influenced by the sludge index as is clearly shown by Figure 3. If that fact is not fully appreciated the operator may encounter serious complications in attempts to regulate *weight* of suspended solids in his aerators.

If the test is to be used the operator should first make sufficient trials to prepare a graph similar to Figure 3. Once such a graph is available he may determine the sludge index once a day and from that determination and the graph he can select the desirable centrifugal test results for the more frequent determinations made on the mixed liquor, return sludge, etc.

To substantiate this assumption we submit Table I. Sample 6 was a sample of the return sludge from the Salinas plant; samples 1 to 5, inclusive, were prepared by diluting sample 6 with varying amounts of final effluent that had been collected at the same time.

TABLE I

Sample	Suspended Solids % by weight "A"	Settleable Solids % by volume 30 min. standing "B"	Sludge Index (B/A)
1.....	0.064	5	78.1
2.....	0.172	15	87.2
3.....	0.289	25	87.2
4.....	0.400	35	87.5
5.....	0.549	50	91.1
6.....	1.078	100	92.8

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(4) C. George Anderson, "Activated Sludge Control at Rockville Center and the Prevention of Bulking."—Sewage Works Jour., 8, 784 (September, 1936).

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"Dry Cleaning" Air Diffuser Plates

By A. M. RAWN

Associate Editor, Los Angeles, Calif.

Every once in a while someone does something that makes one stop and wonder why it has never been done before. Or, if ever done, why he has not heard of it.

Maybe you have been in Southern California when, due to "unusual weather conditions" the winter temperature drops below freezing and the citrus growers start the orchard smudge-pots, to warm up the whole outdoors and keep the crops from freezing. If you have, you may recollect that upon such occasions the air in the orchard areas is so filled with thick, oily smoke that one cannot see a hundred feet. This winter has been such a one and for a number of days early this month (January) millions of gallons of oil have been burned in the smudge-pots.

Now this may not seem to have anything to do with sewage disposal, but strangely enough it does have.

The city of Ontario lies right in the heart of the citrus grove area and, in consequence, was encompassed in a dense smoke fog for some time. During this period the operator of the Ontario activated sludge plant noticed that the pressure on the air lines was steadily increasing at the blowers. Attributing it to the oily carbon in the air, as most likely responsible for the clogging of the diffuser plates, he made every effort to cleanse the air by straining it through several thicknesses of cloth over the air inlet to the blowers. The cloths were changed frequently but to no avail. And, pressures at the blower mounted from 5 to 7½ pounds over night.

Obviously the diffuser plates, which had operated for more than a year with no building up of pressure, had to be cleaned. The finely divided carbon and oil in the smoke had doubtless spread quite uniformly through the plate pores. The orthodox manner of cleaning would have been to remove the plates and clean them up with a solvent and, if not successful, burn out the volatile materials, possibly. The city engineer had other ideas, however, and instead of bringing the plates to the solvent the solvent was taken to the plates. A scheme for injecting the solvent into the air stream from the blowers was put into operation.

What was actually done was to slowly pump "Aviation" grade of gasoline into the air line and beyond the blower. Two gallons of gasoline was fed into the pipe slowly during a 24-hour period. It did the job all right, because during this period pressures dropped back to normal and the trouble was completly cured. So far, there has been no injurious effect upon the quality of the plant effluent or the behavior of the sludge.

This struck the writer as being a most unique method of overcoming a serious difficulty. Mr. Austin Burt, Ontario's city engineer, was "the brains" behind this "solvent-solved situation"; and H. M. Ely, as chief operator of the plant, was "the brawn."

In his latest advice to the writer the "inventor" of diffuser dry cleaning states: "We have had to apply our gasoline remedy to the diffuser plates *seven* different times during the more than two weeks of smudge conditions. Each time the pressure was brought back to normal, and thus far we have been unable to detect any serious consequences in the operation of the plant. Altogether, we used seven and one-half gallons of aviation gasoline at the total cost of only $1.16 and feel pretty good at saving the trouble and cost of emptying the tanks, removing and cleaning the plates."

*Assistant Chief Engr., Los Angeles County Sanitation Districts.

PRINCIPLES OF POWER GENERATION AND GAS PURIFICATION

Refer to "Principles of Power Generation with Sewage Gas Engines," by Norman C. Wittwer, in the Magazine Section of this Issue.

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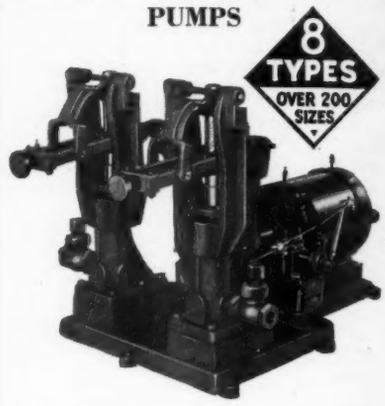
Dowmetal, Brass, Bronze Alloys, Nickel Alloys.

CHEMICAL PROPORTIONING PUMPS



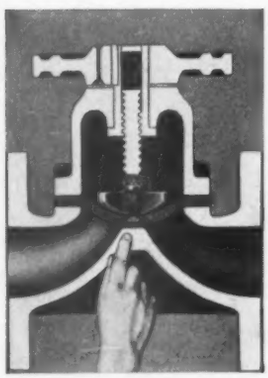
DUAL UNIT MOTOR-DRIVEN "M" TYPE. ONE OF A LARGE SERIES FOR VARIOUS CAPACITIES AND PRESSURES.

Hills-McCanna Chemical Proportioning Pumps are backed by 65 years' experience in the production of metering devices and are designed to provide an exacting mechanical means for feeding or controlling the injection of water, acids, alkalis, salt solutions, oils, solvents, molten materials, dyes, perfumes, etc., against high or low pressures.

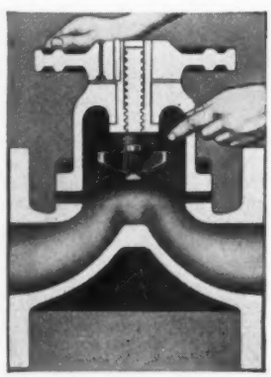
The pumps are of the constant speed variable stroke type, of simple design and ruggedly constructed to offer long trouble-free service. The pumping mechanism consists of a single plunger with outside deep packed stuffing boxes. Ball, plunger or mechanically-operated check valves are provided.

Single, dual or multiple units are available. Volume ratings range from 0 to 1500 gallons per hour. Pressures up to 12,500 lbs. P.S.I. Special assemblies can be had.

Send for Catalog.



VALVE CLOSED
Diaphragm compressed between follower and body weir, forming a perfect leak-proof closure.



VALVE OPEN
Diaphragm raised — note working parts sealed from liquids . . . streamlined flow . . . no grooves or pockets.

The Hills-McCanna Saunders' Patent Valve is different from any conventional valve, being based on a new principle of design, wherein a tight closure is obtained without accurately fitted parts. Operating mechanism is completely isolated from the thru-put. The valve comprises only two units with a tough resilient moulded diaphragm in between. This two unit construction is noteworthy because it permits the use of corrosion-resistant materials for the body, while the Bonnet can be of standard cast-iron. Valve bodies are available in cast-iron, lined with glass, rubber, or lead or any machineable alloy, as well as Haveg or stoneware.

Services such as acids, alkalis, viscous substances, semi-solids, pulp, etc., can be handled successfully. Ordinary wear, suspended solids in solution, etc., cause no difficulty since the enveloping action of the diaphragm assures a perfect closure.

The chemical valve is available in ½" to 14" sizes with standard flanges. Also, screw type in ½" to 3" sizes. Pressure limit, 150 lbs. P. S. I. Temperature limit depends upon service. Special catalog gives full particulars.

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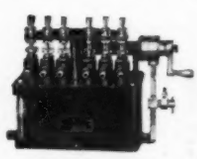
3 TYPES SINGLE OR MULTIPLE FEEDS.

Hills-McCanna "The original oilers" employ the single plunger principle with packed stuffing box and ball valves. A positive and dependable means of lubricating bearings and stuffing boxes under high or low pressures. Available with drives to suit conditions for centrally controlled or individual applications. Write for special catalog.



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MODEL "GB" GLASS BODY TYPE FOR BOILER ROOM AND MARINE USE.

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Triple Seal Piston Type for old or new cars. Stop leaks at loading rack, or while car is in transit.

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FERRIC CHLORIDE

Practical Aspects of Storing and Handling

By L. L. HEDGEPETH and J. M. POTTER[2]
Philadelphia, Pa.

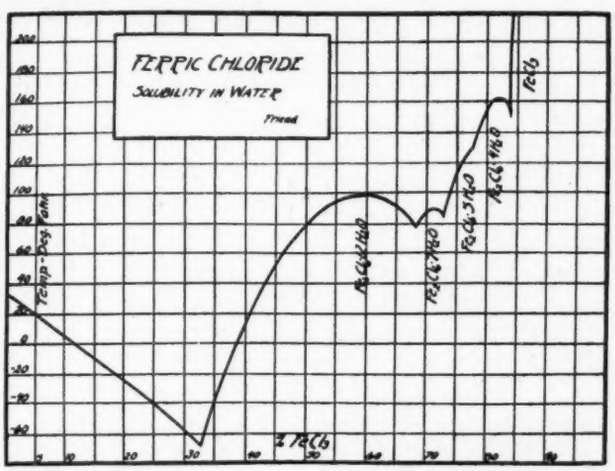
The steady advance in the utilization of chemicals in sewage treatment has created an increasing interest among engineers and municipal officials in the problems involved in their use.

The object of this article is to supply a concise outline of the more significant properties of ferric chloride and effective methods of handling and storing it.

At this time there are three commercial forms of ferric chloride available:

1. *Liquor*—An aqueous solution which is prepared to contain between 39 and 45 per cent $FeCl_3$ by weight to meet exact specifications.

2. *Crystals*—A definite crystal of the formula $FeCl_3.6H_2O$ containing 60 per cent $FeCl_3$ by weight.



Solubility of Ferric Chloride at Varying Temperatures. Note that a 45 Per Cent Solution will Crystallize at About 52 Degrees F.; a 33 Per Cent at Zero.

3. *Anhydrous*—A complete water-free form containing 98 per cent or more $FeCl_3$ by weight.

Liquid Ferric Chloride

Commercial ferric chloride liquor is a dark brown, somewhat oily appearing aqueous solution of varying concentrations. Obviously for the lowest transportation cost, the $FeCl_3$ content of these solutions should be as high as possible but concentrations are limited by crystallizing temperature conditions during transit or storage. To prevent crystallization the strength of solutions usually varies from 45 per cent in midsummer to 39 per cent $FeCl_3$ in midwinter. Average concentration of shipments over a period of several years has been 42 per cent.

Shipments are made in rubber-lined tank cars holding 8,000 gallons and averaging 40,000 pounds of dissolved $FeCl_3$ per car. The dome of the tank car is equipped with sump and center level discharges, a filling and air pressure pipe with gauge connection and a rubber disk safety valve which relieves at gauge pressures exceeding 25 pounds. The car is unloaded by attaching a rubber hose to the discharge connection and siphoning in case of low level storage tanks or by applying air pressure up to 25 pounds where a lift is required.

The maximum lift by air ejection is limited to 40 ft. If higher lifts are necessary a suitable pump should be provided.

Ferric chloride liquor (referred to in the trade as liquid ferric chloride) is easily handled and is usually the most economical form for use by the large consumer, who is reasonably near a source of supply. However, it has the disadvantage of requiring transportation costs on its 58 per cent (average) water content, railroad siding facilities, and storage tanks for one or more cars.

Storage Tanks

Except for its strongly corrosive nature, ferric chloride liquor offers no storage hazard, the only storage problem being provision of sufficiently large ferric chloride resistant tanks to store one or more carloads. *Ten thousand gallons should be the minimum storage capacity for plants using tank cars of ferric chloride.* Wood, reinforced concrete, or steel tanks lined with rubber with all exposed exterior surfaces painted with a ferric chloride resistant paint are the ideal containers. Covered tanks need not be sheltered but, in the case of unsheltered tanks, the strong liquor received during warm weather should be diluted in the storage tanks during the colder months to prevent crystallization. If possible, storage tanks should be elevated to permit the liquor to flow by gravity to dilution tanks or feeders, thereby confining all pumping to the simple air lift unloading operation from the car.

The concentrated ferric chloride solution taken from storage is preferably diluted to a 2 or 3 per cent solution when applied by one of the methods noted later in this article under "Feeding Equipment." Rubber-lined wood tanks under cover serve the Sewage Treatment Works of Milwaukee.

Crystal Ferric Chloride

Crystal ferric chloride is the oldest commercial form. As indicated in the accompanying graph, four hydrated crystals of ferric chloride can be formed; but, only the dodecahydrate, $Fe_2Cl_6.12H_2O$, (commonly written $FeCl_3.6H_2O$) is now commercially available. This material contains 60 per cent $FeCl_3$ by weight, is in the form of large yellow or brown lumps, has a melting point of 98.6° F., is slowly soluble in water at average tap temperatures, and is moderately hygroscopic.

The crystals are marketed in non-returnable, hardwood, paraffine-lined barrels of 55 gallons' capacity, which contain approximately 435 pounds of material. To prevent melting, and possible leakage, it is advisable to store barrels in single tiers under dry conditions at temperatures below 98.6° F. *The storage space required is approximately 70 square feet per ton of $FeCl_3$.*

Equipment for preparation of solutions and feeding crystal ferric chloride will be discussed in connection with anhydrous ferric chloride solutions, because of the close similarity of each.

Anhydrous Ferric Chloride

Anhydrous ferric chloride occurs rarely in nature, possibly the only source being the lava of Vesuvius. It takes the form of small greenish-black crystals with a melting point of 577.4° F., and is extremely hygroscopic, being readily soluble in water to 45 per cent concentrations at room temperatures above 55 degrees. The solubility curve for crystal ferric-chloride applies also to the anhydrous salt.

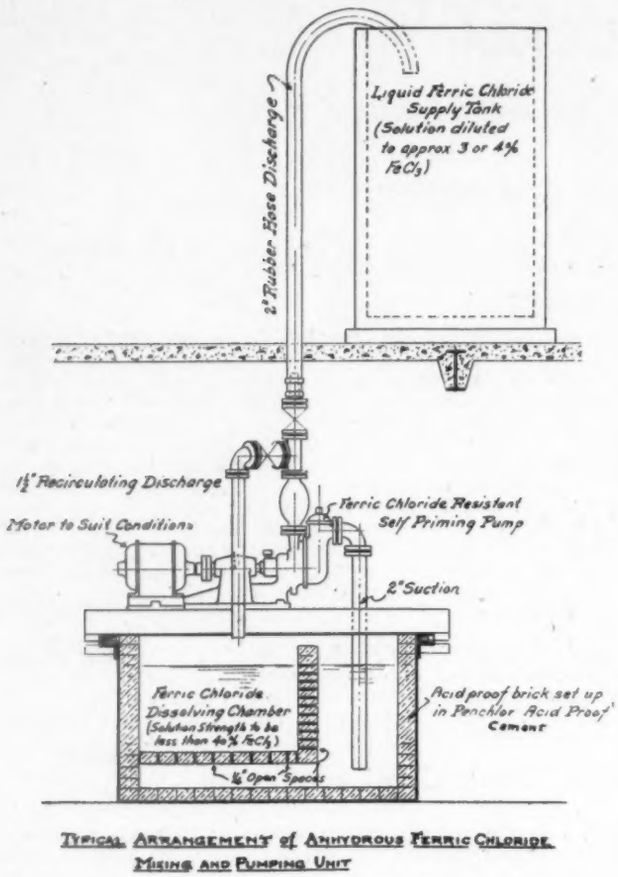
At present, the anhydrous form is being shipped in non-returnable steel drums holding 150 pounds of material. The drums, 15½ inches in diameter by 20 in height and weighing 10 pounds, are fitted with a 9-inch air-tight gasket and lid held in place by 4 screw bolts. These drums are convenient packages which may be stacked and stored indefinitely without deterioration. *Storage space required is approximately 40 cubic feet per ton of $FeCl_3$.*

Anhydrous ferric chloride has a decided advantage over the other forms by reducing transportation costs and storage space requirements 40 per cent or more. In addition, waste by leakage or deterioration is eliminated.

Preparation of Solution, Feed Methods And Equipment

The hygroscopic character of ferric chloride prohibits the use of dry feeds. The corrosive nature of solutions prevents the use

[1]Director, Technical Service, Pennsylvania Salt Manufacturing Co., Philadelphia, Pa.
[2]Former Service Engineer.


Liquid Ferric Chloride Supply Tank (Solution diluted to approx 3 or 4% FeCl3)
2" Rubber Hose Discharge
1½" Recirculating Discharge
Motor to Suit Conditions
Ferric Chloride Resistant Self Priming Pump
2" Suction
Ferric Chloride Dissolving Chamber (Solution Strength to be less than 40% FeCl3)
½" Open Spaces
Acid proof brick set up in Penchlor Acid Proof Cement
TYPICAL ARRANGEMENT of ANHYDROUS FERRIC CHLORIDE MIXING AND PUMPING UNIT

Sketch of Trouble Free Equipment and Method of Dissolving, Diluting and Feeding Ferric Chloride.

of ordinary piping and feeding equipment. A 20 per cent ferric chloride solution rapidly attacks the common metals and dehydrates wood, causing it to warp and shrink. Wood, or reinforced concrete, resists the action of weak solutions since excessive hydrolysis forms a protective hydrate coating. Equipment made of, or lined with, rubber, glass, Bakelite, or ceramic material, or the resistant metals such as Durichlor, or Hastelloy "C," will resist all concentrations of ferric chloride at normal temperatures. Rubber, glass, or ceramic materials may require additional protection against mechanical abrasion, or heat variation.

Feeding apparatus may vary from a simple solution tank with constant head orifice box to a modern "electric eye" controlled installation such as that used at the Chicago Sanitary District. The ideal and foolproof method of feeding involves 3 distinct steps: (1) Solution, (2) Dilution, (3) Application.

Dissolving Tanks

Solution tanks are necessary for dissolving either the crystal or anhydrous ferric chloride. Concentrations of less than 40 per cent are recommended to prevent crystallization and, in the case of anhydrous ferric chloride, high temperatures at the time of preparing the strong solution.

Solution strengths should be determined by adding a weighed quantity of ferric chloride to a definite volume of water as hydrometer measurements have proved to be unreliable. The tank should be at least partly filled with water before adding anhydrous ferric chloride to prevent the formation of the slowly soluble higher crystals and if the total contents of a drum are not added at one time the lid should be tightly replaced. Solution tanks of steel, reinforced concrete, or wood, lined with rubber and faced with acid-proof brick and cement, and of sufficient size to dissolve a 12 hour supply of ferric chloride, are preferable. A material rack, or compartment, and mechanical means of agitation are desirable features. Here illustrated is such a tank in connection with a pump which serves the dual purpose of agitating and lifting the concentrated liquor to the dilution tank above. The solution may be raised to the dilution tank by a vacuum lift if prepared.

Dilution Tanks

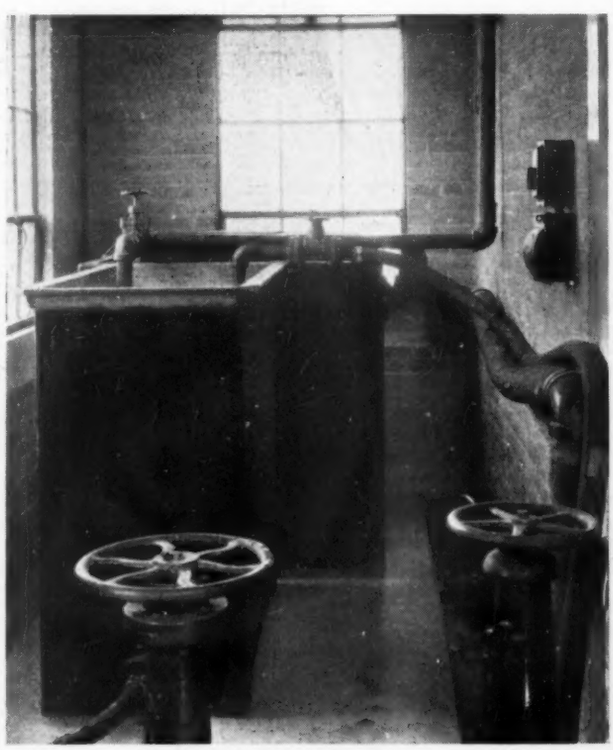
Dilution tanks are advisable for preparing and supplying uniform solutions to feeders. Concentrated solutions are diluted to 3 or 4 per cent $FeCl_3$ by adding gauged volumes of water and liquor. Experience indicates that stronger than 5 per cent solutions exhibit intense localized reaction on application and solutions weaker than 2 per cent may be appreciably hydrolyzed, especially by diluting waters of high alkalinity. Dilution tanks may be similar in construction to solution tanks without the acid-proof brick facing. Reinforced concrete tanks painted with a ferric chloride resistant paint, or large stoneware crocks are suitable. Other desirable features would include a mechanical stirrer, a graduated gauge rod, or glass, and a capacity for at least 4 hours' supply of solution. A tank with the depth exceeding other dimensions is preferable for more accurate gauging.

Solution Feeder

A positive displacement or a variable siphon head type of solution feeder is recommended for applying ferric chloride solutions. Several such corrosion resistant feeders, which have entirely corrected the uncertain performance peculiar to the old orifice type feeder, are on the market today. These feeders may be either manually or automatically regulated. Space does not permit even a limited discussion of all such feeders but following is a list of manufacturers: Galigher Company, Salt Lake City, Utah; Hills-McCanna Co., Chicago; Omega Machine Co., Kansas City, Mo.; Phipps & Bird, Inc., Richmond, Va.; Proportioneers, Inc., Providence, R. I.; Wallace & Tiernan, Inc., Newark, N. J.

Obviously, a gravity flow from solution tank to the final point of application is the ideal feeding arrangement. When lifting is necessary, any method which employs ferric chloride resistant materials may be used. Rubber-lined or hard rubber pumps, pipe and fittings are satisfactory for handling ferric chloride solutions at normal temperatures. Equipment made of Durichlor, or Hastelloy "C" is recommended for hot solutions.

For simple coagulation of sewages with ferric chloride, water purification practice for flocculation and sedimentation will give the best results. For sludge conditioning rapid agitation for 5 or 6 minutes followed by continuous filtration is preferable to the batch method.



Ferric Chloride Service Tank—Rubber Lined. Note Hose Connections and Hills-McCanna Co.'s "Saunders" Pinch-type Diaphragm Valves for Corrosive Liquids

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DOW FERRIC CHLORIDE

60% crystals — 38-45% solution

FOR SEWAGE COAGULATION

- **Greater removal of suspended solids.**
- **Lower 5-day B.O.D.**
- **Increased flexibility to meet peak loads and low stream flows.**
- **Economical effluent improvement.**
- **Reduction of hydrogen sulphide odors.**

FOR SLUDGE CONDITIONING

- **Minimum chemical and operating costs.**
- **Cuts dewatering equipment cost — increases performance.**
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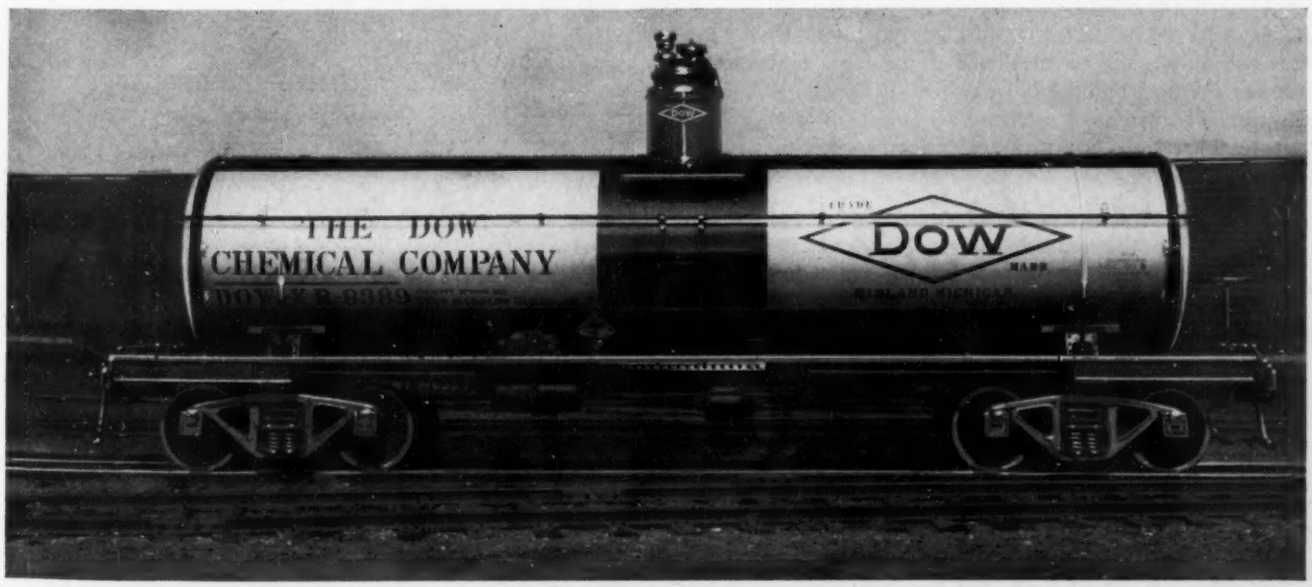
FOR WATER TREATMENT

- **Forms a compact, quick settling floc with complete precipitation at any pH value above 5. Retains effectiveness in cold weather.**
- **Effectively removes large quantities of coloring matter. Precipitates tannin compounds at pH of 5 or below.**
- **In conjunction with lime, removes iron and manganese.**
- **Reduces taste and odor by removing H_2S.**

Dow Ferric Chloride 38-45% Solution is shipped in tank cars. Ferric Chloride 60% Crystals are packed in 300 lb. and 500 lb. heavy wooden barrels, permitting storage without deliquescence of the crystals.

Dow Technical Service covering design and operating problems of sewage disposal plants is available upon request to engineers.



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NIAGARA FALLS, NEW YORK

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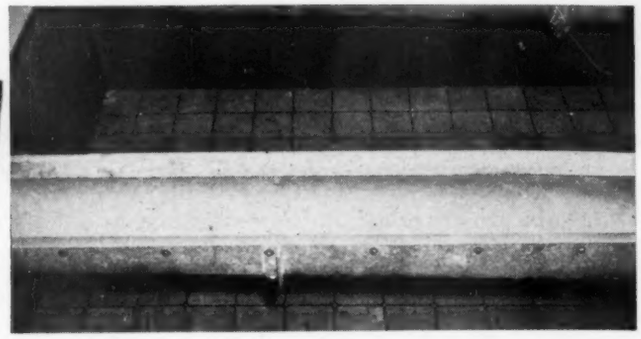
FOR WATER FILTRATION PLANTS . . . Adoption of this new and outstanding development in filter plant design is widespread. The advantages such as elimination of gravel, uniformity of backwash, retention of sand and the many operating benefits derived therefrom, are being continually proved in every installation—For further information and details of design and installation write for Engineering Bulletin No. 2.



ALOXITE BRAND POROUS DIFFUSER PLATES AND TUBES

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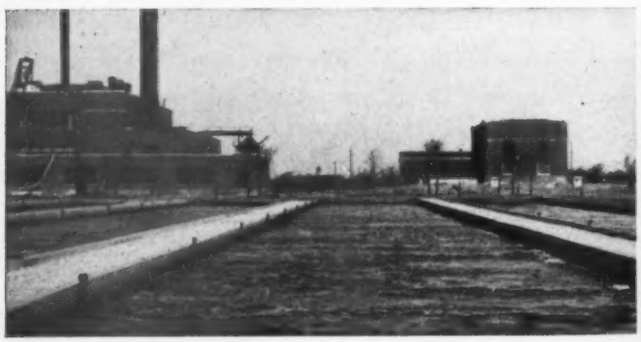

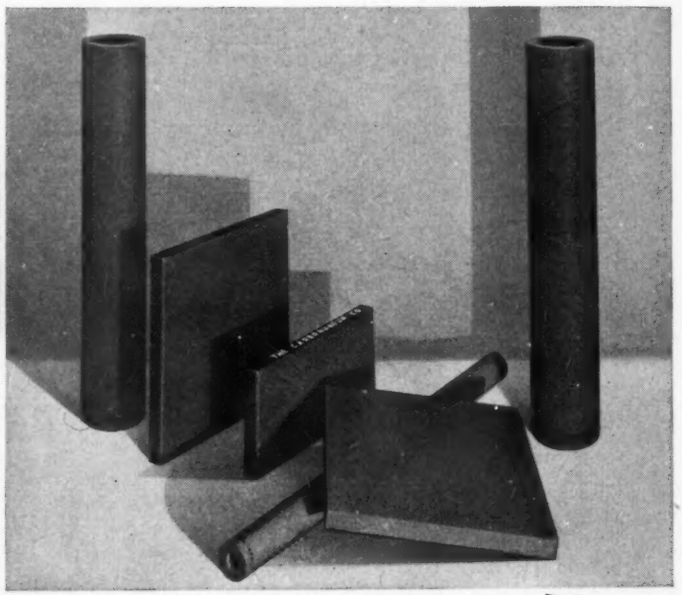

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SERVICING OF POROUS AIR DIFFUSERS*

By FRANK C. ROE

Director of Sanitary Sales, The Carborundum Co., Niagara Falls, N. Y.

To maintain the high efficiency of porous diffuser plates and tubes of the type used for aeration in sewage and water treatment plants, their operation should be checked regularly. Partial clogging of the porous structure may occur for a number of reasons, thereby decreasing the effectiveness and increasing the cost of aeration.

The writer and his company have made a study of the various methods of servicing diffusers necessary to maintain their efficiency for a reasonable life.

The most immediate and positive indication of obstruction within the diffuser structure is an increase of compressor or blower pressure necessary to supply a given quantity of air. Visual examination of the aeration tank or tanks will also disclose non-uniformity of diffusion which may be due to a partially clogged condition. This is a practical determination but not so conclusive as the first.

Diffusers may become clogged on either the air side or on the liquor side; that is, on the top or bottom of plates and on the outside or inside of tubes. Both classes of clogging may be experienced simultaneously, but are avoidable to a great extent.

Liquor Side Clogging

1. *Suspended Solids*: Perhaps the most common type of clogging is caused by interruption of aeration during which the solids in water, sewage, sludge or mixed liquor settle and the water content filters through the diffusers into the air duct. Most of the solids in suspension are intercepted at the diffuser surface, but a definite proportion, depending on the pore size, will enter the top 1/16 to ⅛ inch of the structure. When aeration is resumed all of these particles will not be blown out of the structure and cumulative clogging results.

Maintenance of continuous air delivery, at least to some degree, is the positive way to preclude this trouble. Temporary cessation of the air supply is not impossible with modern equipment, but the usual auxiliary blowers with standby power units and inexpensive automatic control equipment will largely eliminate shutdowns.

Care should also be taken not to over-design in the matter of diffuser area. Not less than one cubic foot of air per minute should normally be discharged per square foot of diffuser area. Insuring a higher rate, so as to maintain good air velocity through the pores as well as uniformity of diffusion from the entire diffuser area, is better practice still.

2. *Organic Growth*: Another form of liquor side clogging is growth of bacterial and protozoa life in the uppermost portion of the porous structure. This may be attributed, at least partially, to non-uniformity of diffusion. All of the diffusers controlled by a single valve may not have similar permeability ratings, or the individual areas of any particular diffuser plate or tube may not be uniform one with another.

As suggested, it should be possible to avert clogging of this nature by careful installation and selection of plates or tubes. All units controlled by a single air valve should have a similar permeability rating within limits of 0.5 cu. ft. or less. Uniformity of individual diffusers depends upon precision and perfection in manufacturing.

*Excerpts from an article appearing in WATER WORKS AND SEWERAGE, April 1934.

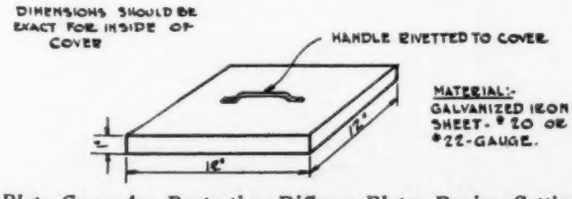

DIMENSIONS SHOULD BE EXACT FOR INSIDE OF COVER
HANDLE RIVETTED TO COVER
MATERIAL:- GALVANIZED IRON SHEET- #20 OR #22-GAUGE.
12"

Plate Cover for Protecting Diffuser Plates During Setting

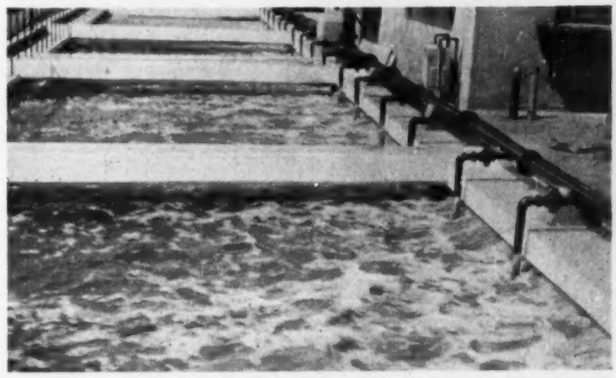


Plate 1—A Section of Aeration Tanks (Sewage Treatment Plant, Golden Gate Park, San Francisco), an Example of Uniform Diffusion

3. *Miscellaneous*: Very often protection from cement grout (or other material used to install plates), dirt, debris, etc., is not provided during installation or when tanks are empty, and appreciable surface clogging results. A plate cover (see sketch) should be used to shield plates from cementing materials during installation, and other protective measures should be observed when tanks are empty.

Air Side Clogging

1. *Dirt in Air*: Air containing a high quantity of soot or other impurities is a major source of clogging on the underside of diffuser plates or inside of diffuser tubes. Selection of effective air filters and care in locating the air intake are obvious preventatives.

The thought should be injected here that diffusers of higher permeability than the type used during the early days of sewage aeration are undoubtedly subject to less clogging of this nature because of relatively larger pores through which many of the fine suspended particles pass rather than stop. It is doubtful if the air bubbles released from higher permeability diffusers are very much larger than the bubbles discharged from the earlier low permeability grade of diffuser. The fact remains that higher permeability diffusers have not been less effective than those of lower ratings previously specified.

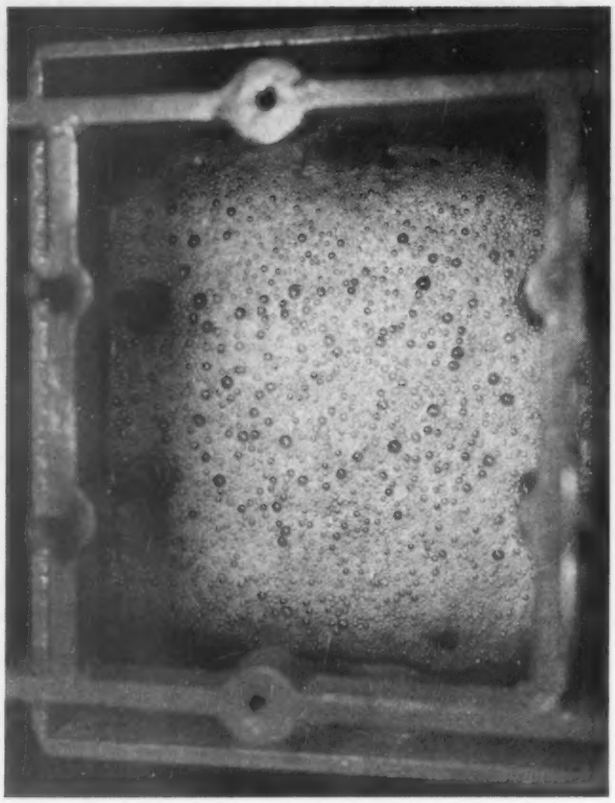
2. *Oil in Air*: Reciprocating compressors are now rarely used in sewage aeration, but the oil which they force through air lines is responsible for pronounced diffuser pore plugging. Fortunately, the low pressure required for sewage aeration permits the use of rotary blowers of the centrifugal or positive displacement type. If reciprocating units must be used for any reason, an oil trap or filter of some kind should be used between the compressors and the diffusers.

Certain types of primary air filters depend on the use of an oil for cleaning or renovating. In this operation it is recommended that a partial wash with a solvent be given after the oil treatment so that oil will not be blown free and carried through the diffusers.

3. *Air Pipe Rust or Scale*: It is generally recognized that cast iron pipe as a material for air lines is sufficiently resistant to corrosion from moisture to be considered to have almost an endless life. Genuine wrought iron is likewise considered satisfactory. Galvanized or sherardized steel pipe would be considered suitable for relative short periods of life, while ordinary black iron pipe or steel is not suitable.

In spite of the consideration given to this phase of air pipe design, there is evidence that some air side clogging is caused by iron oxide in the form of rust particles and scale.

There are economic considerations involved in preventing this source of clogging. Aluminum and copper pipe have been used



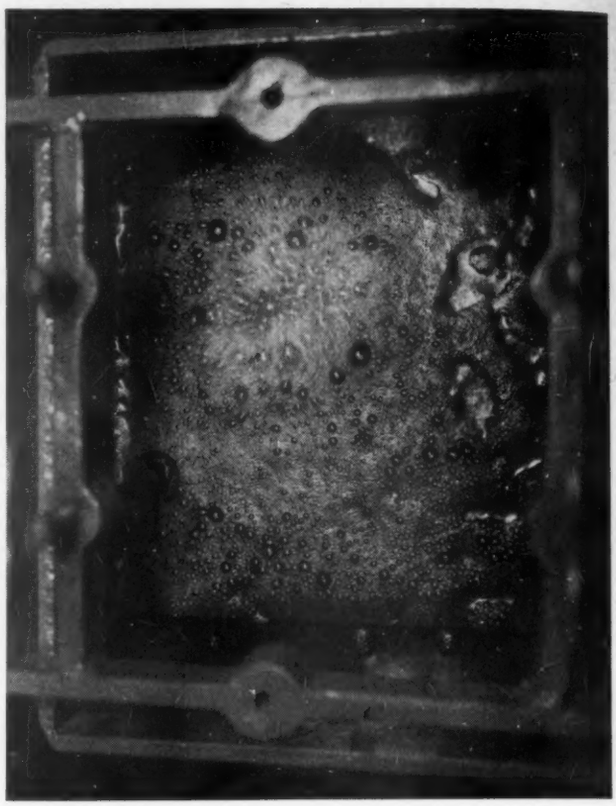


Plate 2—An Illustration of Good Uniformity of Diffusion on the Left; Poor Uniformity on the Right. (Photographs Taken Looking Down on Diffusion Plates in Testing Apparatus)

for the smaller air lines and are recommended along with other types of corrosion resistant pipe. However, if the use of such pipe raises the installation cost appreciably it should be balanced against the estimated cost of diffuser servicing and replacement.

4. *Miscellaneous*: Air lines left in a dirty condition after installation can cause clogging of considerable magnitude. The remedy is obvious. Cast iron diffuser plate containers may cause the same difficulty as does iron piping, but to a lesser degree. Mr. William M. Piatt has avoided this possible source of trouble in designing containers for some of his plants in North Carolina, by using aluminum container linings. At other plants the entire plate holder is to be of aluminum.

Restoration of Diffuser Efficiencies

Because of the diversified types and degrees of clogging experienced in the 100-odd activated sludge plants in the country, it is natural to expect that there are many methods of cleaning in use. Lacking information on the subject, plant superintendents and operators have, more or less successfully, devised and developed individual methods of their own.

Plate Cover for Protecting Diffuser Plates During Setting

The writer's company, in addition to considerable experimental work in the research laboratories. has fostered a survey among those in charge of plants throughout the United States and Canada, believing that many practical methods of diffuser cleansing would come to light. The response to our inquiries and the cooperation received has been most gratifying and has made it possible to present the outline to follow. Some of the methods have been improved, amplified or supplemented as the result of certain research work which we have conducted.

Methods employed in diffuser cleaning can be divided into two general classes; viz., methods applicable to diffusers in place (suitable largely to liquor side clogging) and methods which are adaptable only to removed diffusers. Tubes are cleaned for the most part by the latter method because they may be quickly and easily removed. The methods to follow are not given in an order to indicate preference.

Cleaning Diffusers in Place

1. *Caustic Treatment*: Clean aeration tank and surface of diffusers thoroughly with hose stream and leave about ½ in. of clean water over plates, providing the slowest practical air diffusion during this period. Dissolve about 1/10 lb. commercial lye crystals over each square foot of plate and then shut off air. Allow solution to penetrate plate (10 to 15 minutes), add more clean water, and then turn air on a maximum rate. (Note: This method is chiefly applicable to removal of organic compounds.)

2. *Sand Blasting*: Dry plates thoroughly by draining containers completely and blowing out porous structure with air

Plate 3—Diffuser Plates Stacked in Furnace for Burning-Out of Organic Matter. (More Clearance Between Plates Preferable; See Method 14)

applied at high rate. Sand blast plate surface with usual type of sand blast equipment, using "Blastite" Grain. Remove not more than 1/32 in. from surface, ***maintaining maximum air discharge during the operation.*** One minute or less is required to clean a plate by this method.

3. *Surface Spalling*: Dry plates by draining containers and blowing out porous structure with air at high rate. Apply oxy-acetylene flame with oxygen at 10 lbs. pressure and gas at 5 lbs. pressure. The flame should be applied almost parallel to the diffuser surface, i. e., at as acute an angle as possible. Remove from .010 in. to .015 in. of diffuser surface. Sweep off and rub surface smooth with a Carborundum rubbing block. Sweep off particles again. Leave air on during entire operation.

4. *Burning Out Surface*: Dry plates by draining containers and blowing out porous structure with air at high rate. With air off, saturate each plate with one quart of alcohol and apply heat with blow torch. Dry and brush off surface.

5. *Acid Washing and Scrubbing*: Dry plates by draining containers and blowing out porous structure with air at high rate. With air off, apply a 30 per cent solution of hydrochloric (muriatic) acid to the surface liberally and allow same to penetrate somewhat before turning on air at a low rate. Scrub with a stiff brush, using more acid if necessary. Follow with a clean water wash and scrubbing with a wire brush, continuing air discharge at a somewhat higher rate. (Note: This method is chiefly applicable to removal of inorganic compounds.)

6. *Vacuum Cleaning*: This method has not been proven but was suggested by authorities at the Milwaukee Sewage Treatment Plant, where a trial was intended. A vacuum pump was to have been used with a suction inlet of small area which would be held closely against and moved back and forth across the diffuser surface to be cleaned.

7. *Rest*: Dry plates by draining containers and blowing out porous structure with air at high rate. Allow diffusers to rest while dry for a week or more. (Note: The theory of this treatment is that the change of conditions will cause the bacterial and protozoa growth in the porous structure to die.)

8. *Chlorine Treatment*:* Introduce a strong dose of chlorine into the branch air line leading to each diffuser assembly for several minutes during a low rate of air flow. Following by blowing out diffusers with the maximum possible rate of air flow. (Note: This method is chiefly applicable to removal of organic compounds and carbonates.)

9. *Steam Backwashing*:* Dry diffusers by draining and blowing out porous structure with air at high rate. Introduce steam into the branch air line at 10 lbs. pressure and scrub diffuser surface simultaneously with a stiff brush.

10. *Water Backwashing*:* Introduce clean water into the branch air line under pressure of 15 to 20 lbs. per sq. in. Scrub diffuser surface simultaneously with a stiff brush.

Cleaning Removed Diffusers

11. *Acid Pickling*: Wash diffusers with water (use hose and brush). Set in a vertical position and allow to drain and dry as much as possible. Soak in 30 per cent solution of hydrochloric or nitric acid for four hours. Wash with water. (Note: Use Hydrochloric acid if it is desired to dissolve inorganic compounds and nitric acid if it is desired to oxidize organic compounds.)

12. *Caustic Treatment*: Place diffusers in vessel containing a 10 per cent solution of sodium hydroxide (lye) and boil for about one hour. Remove from this solution and wash thoroughly in boiling water. (Note: This method is only applicable to partial removal of organic compounds, chiefly fats, which are saponified by the caustic soda and then dissolved in hot water.)

13. *Sandblasting*: Dry diffusers thoroughly (preferably in an oven of some kind) and sandblast (Method 2) on either or both sides, as required. It is recommended that, where practicable, the diffuser be inserted in a container which will make it possible to force air through it at a high rate during the operation. This will eliminate any clogging by the dust created.

*Methods applicable to tubes or plates and of some benefit also in cleansing the air size of diffusers.

14. *Burning*: This method is applicable to diffusers of the fused crystalline alumina type. Place diffusers in a furnace or kiln in any convenient position, leaving a space of not less than ¼ in. between units. Raise temperature gradually during 10 hours to about 1000 deg. Centigrade and then allow to cool gradually. The cycle should take at least 16 hours. Fuel of any kind is satisfactory, but care must be taken to avoid impingement of flame against diffuser surfaces. At Decatur, Ill., gas from sludge digestion was used.

Selection of Method

Every plant operates under conditions peculiar to itself, which will prove a factor in the ease or difficulty of diffuser servicing and the methods of cleaning which can be, or should be, used. One method may work satisfactorily in one place but be wholly unsatisfactory in another place or at another time.

In general, methods used on diffusers *in place* are not better than 75 per cent effective and range down to as low as 10 per cent where the clogging is almost wholly on the air side. Methods of cleaning removed diffusers are much more effective and are from 60 to 95 per cent effective. It is usually a combination of two or more methods which will produce the best result; because, any single method is not a cure-all.

The combination of causes and degree of clogging vary greatly and therefore it is not possible to give a rating of effectiveness to each method of restoration. It can be stated, however, that acid pickling of removed diffusers (Method 11) followed by burning in a furnace or kiln (Method 14) is 90 to 100 per cent effective, regardless of type or degree of pore plugging. This combination is therefore, recommended where serious clogging exists.

A simple improvised furnace can usually be built at a sewage plant to refire diffusers, other considerations being satisfactory. Where this work proves impracticable in the field, the writer's company will use its kilns at Niagara Falls for refiring when requested. Such arrangements would offer an added advantage in that refired diffusers can easily be retested and rated so that they may be properly re-installed thereafter.

The above suggests the consideration of providing a simple permeability testing apparatus at sewage treatment plants which would be useful in re-rating removed diffusers which have been cleaned at the plant. Even though original markings are retained, which is doubtful, all units will not respond equally to the cleaning method employed and will have a new permeability rating which should be determined when re-installation is made.

For acid pickling (Method 11) a wooden tub is satisfactory. The caustic treatment requires an iron kettle because of the boiling operation. Workmen should use precaution in these methods by wearing rubber gloves, aprons, etc. Tongs can be used to handle diffusers.

Where existing plate containers do not permit simple mechanical plate removal, a joint composed of sand in the bottom ½ in. and cement grout in the top, is recommended for setting plates in holders. This will save time and avoid plate breakage when removal becomes necessary. Plates so installed should be set with a lime mortar under the supporting edges to insure an even bearing.

Conclusion

The practice of regular servicing should be stressed if the diffusers in any plant are subject to a known source of clogging. If this is done, whether it is apparently needed or not, the permeability will be maintained indefinitely, in all probability, and one or more of the simple and least costly methods of revivification can be employed.

Because of the several potential sources of diffuser pore plugging which exist, and because many of these cause air side clogging, the use of plate containers which permit easy removal of plates is recommended. Ease of removal and replacement is one of the important advantages of diffuser *tubes* for smaller plants. In this connection the new "swing" diffuser and stationary diffuser equipment offered by the Chicago Pump Company is highly recommended.

Diffusers of high permeability are less subject to clogging because of larger pores. They operate on a slightly lower air pressure than low permeability diffusers. Because of these advantages, and the fact that effectiveness of aeration is not decreased (compared to that provided by low permeability diffusers), plates of a higher rating are recommended.

SEWAGE SLUDGE INCINERATION*

A Review of Modern Developments and the Status of the Practice

By E. T. KILLAM

Consulting Engr., New York, N. Y.

The problem of adequate and satisfactory sludge disposal has in general constituted one of the most difficult and troublesome phases of sewage treatment. A substantial part of public prejudice against sewage plants may be attributed to conditions resulting from deficiencies in sludge disposal.

The sludge problem ordinarily becomes more serious as plant sizes increase, particularly with respect to the final disposal of the partially dewatered cake. For these reasons the larger cities located on the seaboard have resorted to barging to sea.

While barging has often been established as the most economical of the available tried methods in past years, few engineers are willing to acknowledge that the collection and transportation of material comprising 90 to 95 per cent water, to a point several miles off shore and its dumping into the ocean, is by any means the ultimate goal in sanitation or engineering accomplishment.

Developments in treatment plant equipment during recent years have demonstrated the feasibility of treating sewage essentially without nuisance—in, or adjacent to, closely built up areas. The economic advantages of elimination of long interceptors, and the prevention of deterioration of sewage quality prior to treatment by reducing detention time in interceptors, frequently establishes the desirability of constructing plants relatively close to centers of population instead of at remote locations, essential with some of the older types of plants. The increased importance of satisfactory sludge handling under such conditions has, among other factors, stimulated interest in sludge destruction by burning.

Considerations Involved

In summary, the following factors have directly or indirectly focused attention on sludge incineration:

1. Difficulties in the operation of sludge drying beds, particularly during periods of cold weather, heavy rainfall or high ground water; also difficulties from odor and fly nuisance, and restrictions imposed by the development of adjacent areas for residential purposes.
2. Difficulty in obtaining proper sites for the ultimate disposal of partially dried sludge.
3. The long recognized and established heat value of sewage solids, and the fact that after partial dewatering—the sludge, even with a fairly high residual moisture content, will support combustion without auxiliary fuel.
4. Developments in drying sludge for fertilizer purposes.
5. The desire, at many locations, to include in the sewage plant facilities, a positive and complete method of disposal of sludge.

Methods of Sludge Drying and Incineration

Methods of drying and incineration of sewage sludge may be summarized as follows:

(*A*) *Drying (For Fertilizer)*
- (1) Without Preliminary Dewatering
  - (a) By Spray Dryer, such as at Plainfield, N. J.
- (2) With Preliminary Dewatering on Sand Drying Beds
  - (a) By Rotary Dryers at Grand Rapids, Mich., and Dayton, Ohio
- (3) With Preliminary Dewatering on Vacuum Filters
  - (a) By Rotary Dryers at Milwaukee, Wis.; Pasadena, Calif.; Houston, Texas

(*B*) *Complete Incineration*
- (1) After Dewatering on Sand Beds
  - (a) By Incineration in garbage-rubbish type incinerator of conventional design, contemplated or tried at a few plants with no known case of routine operation
- (2) After Dewatering on Vacuum Filters
  - (a) By Multiple Hearth Type Units for drying and incineration in one-step
  - (b) By Flash Dryer and Pulverized Fuel Type Incinerators, including drying followed by optional incineration

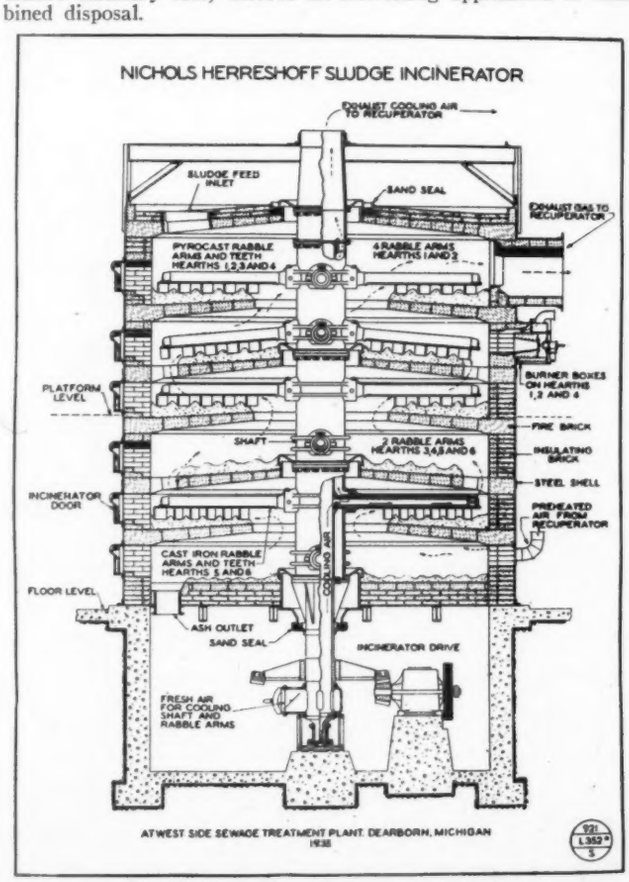
(*C*) *Complete Incineration of Screenings*
- (1) After Partial Dewatering in Roll Press
  - (a) In Hand Stoked Modified Garbage and Rubbish Type Incinerators, at Los Angeles "Hyperion" plant since 1934, and at Westchester County Sanitary District Plants since 1930
- (2) After Partial Dewatering in Centrifugal Machines
  - (a) At Milwaukee in hand stoked modified garbage and rubbish type incinerators
  - (b) At Milwaukee and Niagara Falls in multiple hearth type mechanically stoked—since 1937.

In addition to the foregoing applications of drying and incineration of sewage sludge and screenings, equipment now available offers a variety of special combinations deserving consideration in certain cases, and depending upon local conditions. Of particular interest are the possibilities in the combined disposal by incineration of garbage, rubbish, and sewage solids.

It is well recognized that the properly designed and well operated garbage and rubbish incinerator of today, will, under normal conditions, produce a substantial volume of excess heat.

There are notable examples of effective utilization of waste heat from garbage incineration in producing steam and power. The production of power, however, creates certain demands which must be considered in design and operation, and economical power production will for some time be limited to plants of substantial size.

An alternate use of such excess heat from garbage incineration (namely, as a means to drive off sufficient moisture from the sewage solids to make the sludge combustible without purchased auxiliary fuel) affords an interesting application of combined disposal.


NICHOLS HERRESHOFF SLUDGE INCINERATOR
EXHAUST COOLING AIR TO RECUPERATOR
SLUDGE FEED INLET
SAND SEAL
EXHAUST GAS TO RECUPERATOR
PYROCAST RABBLE ARMS AND TEETH HEARTHS 1,2,3 AND 4
4 RABBLE ARMS HEARTHS 1 AND 2
PLATFORM LEVEL
BURNER BOXES ON HEARTHS 1, 2 AND 4
FIRE BRICK
SHAFT
2 RABBLE ARMS HEARTHS 3,4,5 AND 6
INSULATING BRICK
STEEL SHELL
INCINERATOR DOOR
PREHEATED AIR FROM RECUPERATOR
CAST IRON RABBLE ARMS AND TEETH HEARTHS 5 AND 6
FLOOR LEVEL
ASH OUTLET
SAND SEAL
INCINERATOR DRIVE
FRESH AIR FOR COOLING SHAFT AND RABBLE ARMS
AT WEST SIDE SEWAGE TREATMENT PLANT, DEARBORN, MICHIGAN
1935

The Multiple Hearth Dryer-Incinerator

*A paper presented before the 33rd Annual Meeting of the New Jersey Sewage Trades Association—March 11, 1938.

Incineration and drying of sewage solids has doubtless been retarded due to the recognized item of operating cost, for driving off the moisture in the upper range of moisture content. If heat which would otherwise go up the incinerator stack may be utilized for this purpose, a consequent substantial reduction in operating cost is effected. This saving, combined with other obvious advantages, in many locations, of constructing the sewage disposal and garbage incineration plants at a common site, should make combined wastes incineration worthy of consideration in numerous instances, and the scope of applicability of incineration of sludge will, thereby, be substantially widened.

Inasmuch as the recent installations have been of the multiple hearth type, or the flash dryer and incineration type, these methods will be further discussed in brief.

Multiple Hearth Type Incineration

In 1934 the multiple hearth type incinerator, developed in the mining industry for roasting copper ore, was first applied to the incineration of sewage sludge at Dearborn, Michigan. In this, as in later installations, sludge is partially dewatered on vacuum filters prior to incineration.

The multiple hearth incinerator consists of a refractory lined circular steel jacketed unit, with as many hearths as may be indicated for the specific installation. Rotating plows on each hearth, driven by a vertical hollow air-cooled central shaft, constantly agitate and plow the material during drying and burning. The material drops through staggered openings in each hearth, to the next hearth below, being finally discharged from the bottom hearth in the form of an inert ash.

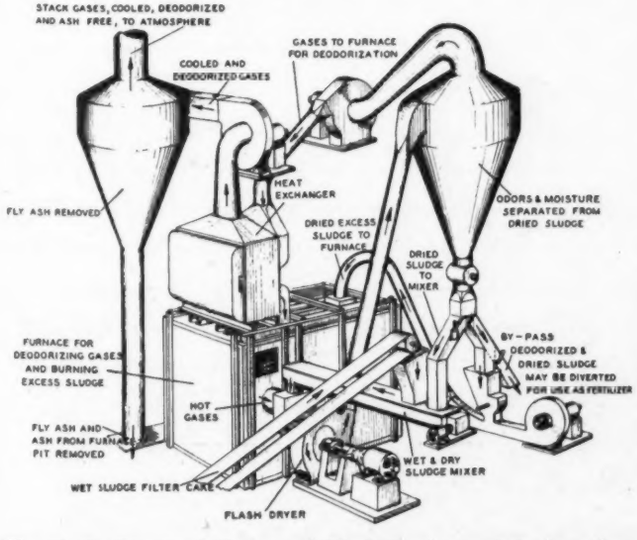
Multiple hearth installations normally include a blower for producing a supply of cooling air for the hollow shaft and revolving arms, a motor for driving the rabble arms, a rotating motor driven feeder, oil burner installation, and temperature control equipment.

In several cases preheaters have been included in the layout. The economic justification for a preheater, by means of which waste gases are utilized to heat the air supply to approximately 900 degrees F., depends upon the plant size, contemplated daily duration of operating period, and character and moisture of sludge to be burned.

The planned range of temperature at the furnace exit is approximately 1100 to 1300 degrees F. under normal optimum operating conditions.

Beginning with the notable pioneering installation at Dearborn, Michigan, in 1934, numerous installations of the multiple hearth type incinerator have been undertaken. Recent reports indicate that equipment of this type has been, or is being installed, in 21 or more plants at this writing.

Installations at various plants to date vary in size from a single 9 ft. 3 in. diameter unit of four hearths, to the largest installation at Detroit, where four 22 ft. 3 in. diameter, 12-hearth units have been installed. It thus appears that America's largest Multiple Hearth Furnace installation is approximately seventy times the size of the smallest installation.


STACK GASES, COOLED, DEODORIZED AND ASH FREE, TO ATMOSPHERE
GASES TO FURNACE FOR DEODORIZATION
COOLED AND DEODORIZED GASES
HEAT EXCHANGER
FLY ASH REMOVED
ODORS & MOISTURE SEPARATED FROM DRIED SLUDGE
DRIED EXCESS SLUDGE TO FURNACE
DRIED SLUDGE TO MIXER
FURNACE FOR DEODORIZING GASES AND BURNING EXCESS SLUDGE
BY-PASS DEODORIZED & DRIED SLUDGE MAY BE DIVERTED FOR USE AS FERTILIZER
HOT GASES
FLY ASH AND ASH FROM FURNACE PIT REMOVED
WET & DRY SLUDGE MIXER
WET SLUDGE FILTER CAKE
FLASH DRYER

The C. E. Raymond System of Flash Drying and Incineration. (This System Makes Permissible Complete Sludge Incineration or a Partial Diversion for Use as Fertilizer. Another Illustration Shows the Cyclone End of the Raymond System in Service.)

The original Dearborn incinerator handles mixed raw chemical and digested Imhoff sludge, the quality of which is indicated by the fact that the long term average volatile content of the cake fed to the incinerator was 46.6 per cent.

Subsequent installations have been in plants which will produce sludge of widely varying characteristics, including the following:

(a) Raw Primary
(b) Raw Chemical
(c) Digested Primary
(d) Raw Activated
(e) Digested Activated

Several units have been purchased for incineration of fine screenings and 5 units have been installed with the expressed intention of handling ground garbage along with the sludge.

The operating records developed during the coming year will undoubtedly produce data of wide interest and great value. It is seldom that a development of equal importance in the sewage treatment field has been simultaneously adopted in such a substantial number of plants, involving so wide a variation of operating conditions, as has vacuum filtration and sludge incineration.

As many of the units went into operation late last year and many will start early this year, a very considerable amount of operating data should be forthcoming within the next few months on the Multiple Hearth Sludge Incinerator.

Flash Drying and Incineration

Flash drying and incineration of sewage sludge was first undertaken on a large scale at the West Side Plant of The Chicago Sanitary District in 1933.

This type of equipment involves incineration in two stages—or in other words the drying of the solids to approximately 10 per cent moisture, followed by incineration of the dried material.

The filter cake, with a normal moisture of 75 to 85 per cent, is mechanically mixed with sufficient dried material to develop proper consistency for drying in the flash dryer. Hot gases and this mixture drop into the flash dryer, are violently agitated, and the dried material and vapors are discharged into a cyclone collector. The dried material—approximately 10 per cent moisture—is mechanically divided, a portion being returned to the mixer for blending with the wet filter cake. The balance, or excess, is sent to storage for fertilizer or to a pulverized fuel type of incinerator for destruction, as the case demands. The vent vapors are likewise discharged to the incinerator.

The average design temperature in the dryer is 1100 to 1300 deg. F., and the temperature of the vent vapors varies from approximately 200 to 300 degrees.

The initial installation—at Chicago's West Side Plant, was designed to dry and incinerate raw activated sludge filter cake at 80 to 85 per cent moisture. The rated capacity is 2,000 pounds net dry solids per hour or 8,000 pounds of water evaporation per hour.

Basing the design upon the performance of this unit, equipment was installed at the Calumet Plant of the Chicago Sanitary District and placed in operation in 1935. Three units—each with a capacity of 6,000 pounds net dry solids per hour, or 24,000 pounds of water evaporation per hour, were included. The sludge handled consisted of raw activated filter cake—with small amounts of grit and heavy primary solids from 20 minute detention primary tanks.

In November, 1937, this same type of equipment was placed in service at Neenah-Menasha, Wisconsin, with a capacity of 0.75 tons dry solids per hour, or 3,500 pounds of water evaporation per hour. The sludge at this plant will at times be digested—primary sludge, and at other times will be chemical sludge. A large proportion of paper mill wastes—with high clay content, has at times developed sludge as low as 35 per cent in volatile content.

Similar equipment is now being installed at Buffalo, New York, for incineration of partially digested primary sludge. This plant includes three units each, with a capacity of 5,000 pounds per hour evaporation.

The largest installation of flash drying equipment is in Chicago's notable South West Activated Sludge Plant, where four units—each served by two drying units, with the latter having an evaporation capacity of 20,000 pounds each per hour, are being installed. In this installation power will be generated from combustion of the pulverant dried sludge, with the assistance of auxiliary powdered coal. In this single plant with a total evaporation capacity of 40 tons per hour, combustion engineering has attained a real goal in sewerage practice in America.

The first installation under contract locally, is at Tenafly, N. J., where a small single unit of the drying apparatus, with an evaporation capacity of approximately 0.35 tons per hour, is

to be installed, for drying raw activated sludge filter cake and fine screenings, preparatory to the burning of the dried material with garbage and rubbish in open hearth incinerator of conventional design.

Summary

In summary, sludge disposal by drying or incineration has constituted one of the most active phases of development, in the past few years, in the field of sewage treatment.

While operating data and operating costs for a variety of installations will soon be available, it can be safely stated that careful consideration of the local conditions in each municipality will be necessary in order to approach the most economical solution of the problem.

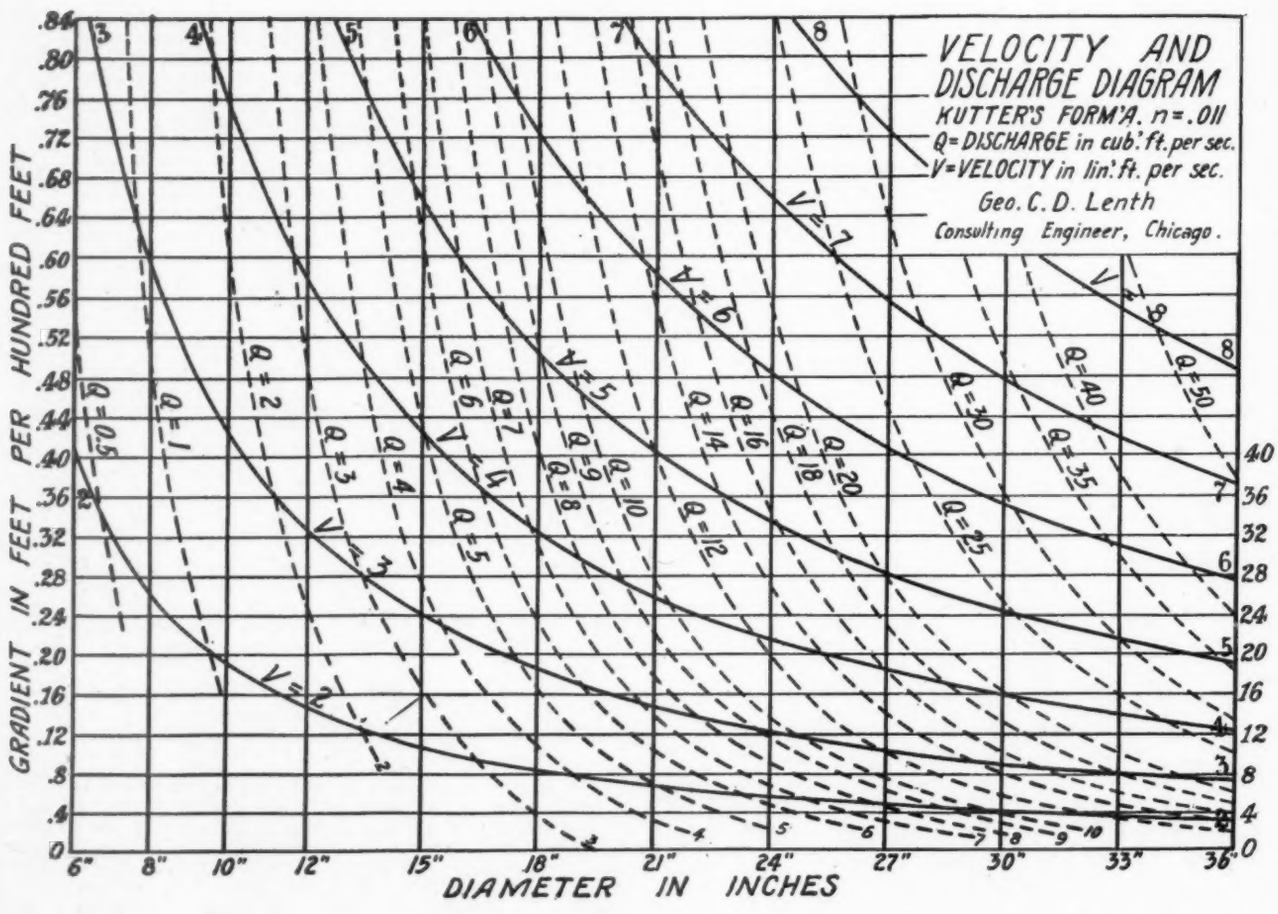
The variables affecting alternate methods of sludge disposal vary no less than the wide range of requirements for degree of sewage treatment. In this way, it would appear that a careful analysis of the problem prior to final selection of the method of sludge disposal, will necessitate thorough consideration of the variables involved.

The characteristics of the sludge and moisture and combustibles content vary widely, depending upon the type of treatment from which the sludge originates. The volatile content of various sludges may vary to as wide a range as from 30 per cent of the total dry solids, to 80 per cent, or even higher. While a heat value of 10,000 B.t.u. per pound of dry volatile matter has frequently been used in computation, additional experience indicates wide variations in B.t.u. content per pound of combustibles.

The demonstrated performance in sludge incineration during the past few years, however, has placed this much needed facility in an important position as a method of sludge disposal. The above variables mentioned will not, it is believed, be of sufficient importance to jeopardize the success of the method, but will affect merely the economic advantages of one method or type of incinerator over another, where incineration is indicated as the preferred method.

Velocity and Discharge Diagram for Vitrified Clay Sewer Pipe

(Courtesy, Clay Products Assn.)


VELOCITY AND DISCHARGE DIAGRAM
KUTTER'S FORM'A. n=.011
Q=DISCHARGE in cub'. ft. per sec.
V=VELOCITY in lin'. ft. per sec.
Geo. C. D. Lenth
Consulting Engineer, Chicago.
GRADIENT IN FEET PER HUNDRED FEET
DIAMETER IN INCHES
6" 8" 10" 12" 15" 18" 21" 24" 27" 30" 33" 36"

(Example: Assume 12 cu. ft. per sec. as the flow to be handled. The gradient for instance, to be a 0.2 ft. per 100 ft. run. Follow to right from gradient figure 0.20 on left until Q12 dotted line is intersected. The vertical line found at that point indicates that a 24 inch sewer is required. Also from the nearest velocity curve V.4 at the intersection it is revealed that the velocity will be 3.8 ft. at full or half full flow.)

THE PARSHALL FLUME FOR MEASURING SEWAGE FLOWS

BY NORMAN C. WITTWER

Sanitary and Hydraulic Engineer, Rahway, N. J.

The Venturi flume in its present form as improved by Parshall[1] is not so generally known as the Venturi tube, and has not been used to any great extent in connection with sewerage practice. However, for measuring the flow of water or sewage in open channels, this device has several distinct advantages.

Collaborating with other experiments, Ralph L. Parshall, Senior Irrigation Engineer of the Bureau of Agricultural Engineering, U. S. Dept. of Agriculture, after making literally thousands of calibrations at the Fort Collins, Colo., Experiment Station, devised the Venturi flume as it is known today, calling it "The Improved Venturi Flume."[1] The American Society of Civil Engineers in 1930 officially changed its name to "The Parshall Flume" in honor of its originator. It was originally developed for use in connection with irrigation, and has since found wide application in the central-west and western irrigation districts.

The Parshall Venturi flume has been applied to the measurement of sewage flows at the Providence, R. I., Sewage Treatment Plant, where a flume with a ten-foot wide throat is being used to measure flows varying from 5 to 120 million gallons per day.[3] At the Walden, N. Y., Sewage Treatment Plant a flume with a 9-inch wide throat is being used to measure flows varying from 5,000 to 1,200,000 gallons per day.[4] At Newark, N. Y., a flume with a 12-inch wide throat is being used to measure all the sewage passed through the sewage treatment plant.[5] Some years ago the writer incorporated a Venturi flume with a 6-inch wide throat into the design of a 1 m.g.d. sewage treatment plant for Maple Shade, N. J., where the available head through the plant was very limited.

Applications

The Parshall flume is particularly advantageous in measuring sewage where the available head is limited, and a nearly flat hydrulic gradient is mandatory. Table I illustrates comparative losses of heads for free-flow through Venturi flumes and over various standard types of weirs.

TABLE 2—STANDARD DIMENSIONS AND CAPACITIES OF PARSHALL'S FLUME

(Letters refer to Figure 1)

Throat Width	Dimensions in Feet and Inches											
W	A		⅔ A		B		C		D		E	F	G
Ft.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	Ft.	In.
0.5	2	1¼	1	4⅞	2		1	3½	1	3½	1	2	4½
1.0	4	6	3		4	4⅞	2		2	9¼	2	3	9
2.0	5		3	4	4	10⅞	3		3	11½	2	3	9
3.0	5	6	3	8	5	4¾	4		5	1⅞	2	3	9
4.0	6		4		5	10⅝	5		6	4¼	2	3	9
5.0	6	6	4	4	6	4½	6		7	6⅝	2	3	9

As stated above, the accuracy of the Parshall-Venturi flume is comparable with that of the standard weirs, and it can be used for any purpose which the standard weirs serve. Its principal applications may be listed as follows:

(1) To measure the entire flow through a plant or pumping station.

†(2) To proportion the flow through units operating in parallel.

†(3) To serve as a control for the automatic dosage of chlorine and other chemicals in proportion to the flow of sewage.

†(4) To measure and control the amount of return sludge in an activated sludge plant.

(5) In a sewerage district, to measure the sewage flows contributed by the various member municipalities.

Principle of the Parshall Flume

By examining Figure 1, it will be seen that the flume converges to its narrow or throat section. As the water approaches the throat, the velocity is constantly increased. It is still further in-

†The Parshall Flume, of itself, naturally can not perform duties 2, 3 and 4 unless the accessory-mechanical equipment, similar to that employed with Venturi Tubes, is provided.

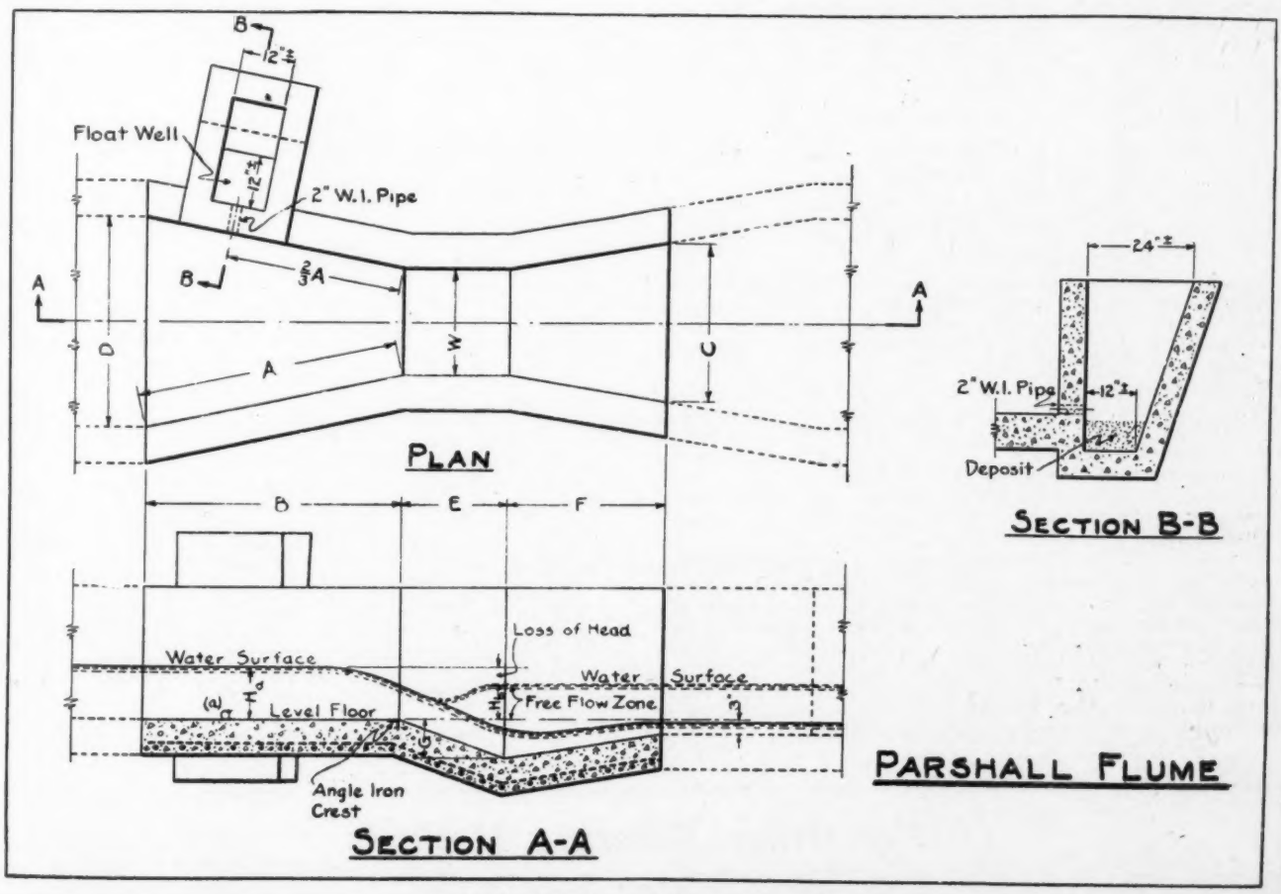


Fig. 1—Parshall Flume in Plan and Section

TABLE 1—LOSS OF HEAD FOR GIVEN DISCHARGES, THROUGH PARSHALL FLUMES AND VARIOUS TYPES OF WEIRS

	Parshall Flume*				Standard Rectangular Weir				Standard Cipolletti Weir				90 Triangular
Discharge Sec. Ft.	6-In Throat, Ft.	1-Ft. Throat, Ft.	2-Ft. Throat, Ft.	4-Ft. Throat, Ft.	6-In. Crest, Ft.	1-Ft. Crest, Ft.	2-Ft. Crest, Ft.	4-Ft. Crest, Ft.	6-In. Crest, Ft.	1-Ft. Crest, Ft.	2-Ft. Crest, Ft.	4-Ft. Crest, Ft.	Notch Weir, Ft.
0.10	0.03	...	...	...	0.15	...	...	...	0.15	...	...	...	0.27
0.50	0.11	...	...	...	0.46	0.29	0.18	...	0.43	0.28	0.18	...	0.52
1.00	0.18	0.13	...	...	0.74	0.46	0.29	0.18	0.64	0.44	0.28	0.18	0.69
2.00	0.31	0.21	0.15	...	1.16	0.75	0.46	0.29	0.96	0.69	0.45	0.28	0.92
3.00	...	0.27	0.18	...	...	0.99	0.61	0.38	...	0.88	0.58	0.37	1.08
5.00	...	0.39	0.24	0.13	...	...	0.86	0.53	...	...	0.82	0.52	1.32
7.50	...	0.50	0.31	0.20	...	...	1.13	0.70	...	...	1.06	0.68	...
10.00	...	0.60	0.39	0.25	...	...	...	0.85	...	...	1.27	0.83	...

*70% submergence.

creased after passing over the "crest," which is the junction of the level upper floor and the throat door at E. With the momentum thus acquired, the water is carried upward over the sloping floor of the diverging section and on through the flume. This unrestricted condition of flow is called "free flow."

If the grade of the channel downstream from the flume is reduced, the water, after passing through the flume, is resisted and checked in velocity, causing a backing up into the diverging section. If the water is backed up sufficiently to cause the surface elevation of the water in the diverging section to attain the same level as that of the crest, a condition of zero submergence is said to exist. Still further backing up of the water will cause the elevation of the water surface in the diverging section to rise, producing what is called a hydraulic jump. Under such conditions, the flow is said to be submerged, the percentage of submergence being the ratio of the throat head (H_b) to the upper head (H_a), both being measured from the crest as a datum. The discharge of the flume is not reduced by moderate percentages of submergence, and is considered as having the characteristics of free-flow below the critical percentages. The 6-inch flume has free-low characteristics up to 50 per cent submergence, and the 1-foot, 2-foot and 3-foot flumes up to 70 per cent submergence. For ordinary installations, Parshall flumes should be installed with freeflow conditions.

Free-Flow Formula: For free-flow characteristics, as stated above, only the gage reading (H_a) at (a) need be measured.

For the 6-inch flume, the formula for free-flow discharge is:

$$Q_1 = 2.06\ H_a^{1.58}$$

or $$Q_2 = 1.331\ H_a^{1.58}$$

For 1 foot to 10-foot flumes, the formula for free-flow discharge is:

$$Q_1 = 4\ W\ H_a^{1.522W^{0.026}}$$

or $$Q_2 = 2.585\ W\ H_a^{1.522W^{0.026}}$$

where Q_1 = Quantity of flow in second-feet.
Q_2 = Quantity of flow in million gallons per day.
W = Width of throat in feet.
H_a = Upper head in feet.

Figs. 2a and 2b are convenient charts for obtaining free-flow discharges for small and medium size plant needs. While experiments have shown the reliability and accuracy of the 6-inch flume above an H_a value of .80 feet, it is advisable to use a larger flume for flows in excess of 1 m.g.d.

Construction: By referring again to Figure 1, it will be seen that the flume has only plane surfaces. It may be constructed of concrete, or if for temporary use, of dressed cypress or white pine properly braced across the top. Two-inch lumber is recommended for the bottom and sides of the timber flume, with 4 by 4-inch sills and posts. If constructed of concrete, the crest should be formed by casting a medium size angle iron in the floor, as shown in Figure 1.

Measuring Sewage Flow: The measuring or recording device may be any of the home-made or commercial types of apparatus ordinarily used for this purpose. It may be an indicating staff gage, a graphic recording float gage mounted over the float-well. Or, in larger permanent installations, an indicating, recording and integrating instrument may be located at a point not far removed from the flume. The readings can be electrically transmitted to distant points such as has been successfully done at the Providence, R. I., Sewage Treatment Works.

Summary:

1. The Parshall flume is adaptable to the measurement of sewage flows.
2. It particularly meets low-head requirements.
3. It is simple and easy to construct.
4. Its maintenance requirements are negligible.
5. It can be connected with any of the conventional measuring and recording instruments.

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3. Glenn D. Holmes—"New Activated Sludge Treatment Plant, Newark, N. Y." Waterworks and Sewerage, May, 1933.
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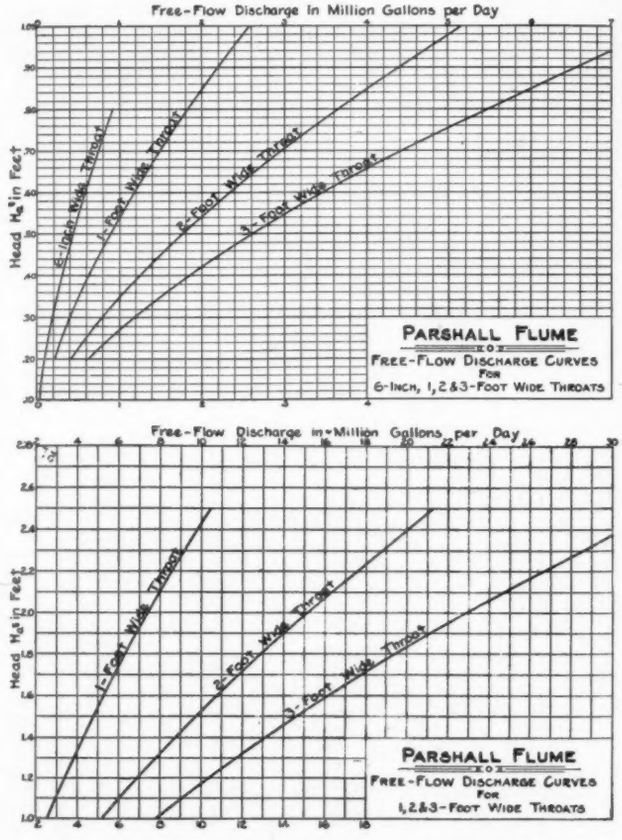

Free-Flow Discharge in Million Gallons per Day
Head H_a in Feet
6-Inch Wide Throat
1-Foot Wide Throat
2-Foot Wide Throat
3-Foot Wide Throat
PARSHALL FLUME
FREE-FLOW DISCHARGE CURVES FOR 6-INCH, 1, 2 & 3-FOOT WIDE THROATS
Free-Flow Discharge in Million Gallons per Day
Head H_a in Feet
1-Foot Wide Throat
2-Foot Wide Throat
3-Foot Wide Throat
PARSHALL FLUME
FREE-FLOW DISCHARGE CURVES FOR 1, 2 & 3-FOOT WIDE THROATS

Figs 2a and 2b—Discharge Curve of Parshall Flume

For Other Metering Methods
See Water Section

ENGINEERING DATA

MENSURATION

CALCULATION OF AREAS, VOLUMES, SURFACES REDUCED TO SIMPLE TERMS

Mensuration is arithmetic applied to geometry in determining the length of lines, the area of surfaces, and the volume of solids or bodies.

Definitions of geometrical terms, figures and principles. A point (.) has position only. A line (———) has length only. Area has length and breadth. A solid has length, breadth and thickness. Parallel means extended in the same direction, and equidistant at all points. Horizontal means parallel with water level; vertical or perpendicular, parallel with plumb line; diagonal, obliquely across a polygon. (Fig. 4.) Equilateral means, having equal sides. Quadrilateral, having four sides. An angle (Fig. 1) is formed by two straight lines diverging from a commont point called the vertex. A right angle (Fig. 2) is formed by two straight lines meeting perpendicularly. An oblique angle is either (acute—Fig. 1) smaller, or (obtuse—Fig. 3) greater than a right angle.

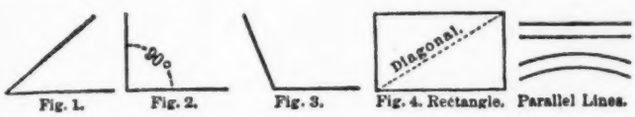


Fig. 1. Fig. 2. Fig. 3. Fig. 4. Rectangle. Parallel Lines.

A plane or plane figure has area or surface only—perfectly even.

A polygon is a plane figure having three or more equal sides.

A triangle is a plane figure bounded by three straight lines.

An equilateral triangle (Fig. 6) has all of its (3) sides equal. An isosceles triangle (Fig. 7) has two of its sides equal. A scalene triangle (Fig. 5) has none of its sides equal. The base is the side on which a geometrical figure is supposed to stand. The least distance between the base and the opposite angle dotted line (Fig. 7) or between parallel lines (Fig. 8) is called the perpendicular or altitude.

To find the area of a triangle. Rule—Multiply base by the altitude and take half of the product. Or, when the three sides are given. From half of the sum of the three sides, subtract each side separately; then multiply the half sum and the three remainders together and extract the square root. Find sq. ft. in a triangle, base 8 ft., altitude 9 ft.

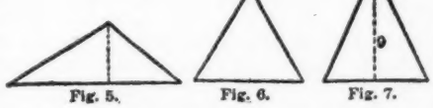


Fig. 5. Fig. 6. Fig. 7.

Answer—$(8 \times 9) \div 2 = 36$.

A parallelogram is a plane figure, bounded by four straight lines, whose opposite sides are equal, as a rectangle, a square, and a rhomboid.

A rectangle is a right angled parallelogram. A square is an equilateral rectangle. A rhomboid is an oblique angled parallelogram.

To find the area of a parallelogram. Rule—Multiply the length by the width.

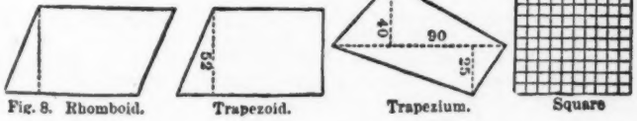


Fig. 8. Rhomboid. Trapezoid. Trapezium. Square

How many sq. ft. in a rectangle 17 by 24?

Answer—$17 \times 24 = 408$ sq. ft.

In a (square) floor 10 by 10?

Answer—$10 \times 10 = 100$ sq. ft.

Note—Dividing the area of a rectangle by one side gives the other side—if unknown.

A *trapezoid* is a quadrilateral having two of its sides parallel. To find its area. Rule—Multiply its average length by the width.

How many sq. yd. in a garden whose parallel sides are 60 and 80 yd., and width 52 yd.?

Answer—$(60 + 80 \div 2) = 70$; then, $70 \times 52 = 3{,}640$ sq. yd.

A *trapezoid* is a quadrilateral having two of its sides parallel.

To find its area. Rule—Form two triangles by a diagonal line, then multiply diagonal by sum of perpendiculars and take half of product.

Find sq. rods in field shaped like a trapezium, whose diagonal is 90 rods, and perpendiculars (25 and 40) 65 rd.

Answer—$90 \times 65 = 5850 \div 2 = 2925$ rd.

A *rightangled triangle* has one right angle. Its longest side is called hypotenuse, and the other two, base and perpendicular or altitude. To find its area. Rule—Multiply the base by the perpendicular and take half of the product.

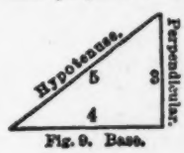


Fig. 9. Base.

How many square rods in a triangular field whose base is 70 rods and the perpendicular, 48 rods?

Answer — $(70 \times 48) \div 2 = 1680$ square rods.

Properties of the rightangled triangle. The square of the hypotenuse equals the sum of the squares of the base and the perpendicular. From this principle—illustrated by Fig. 10—we derive the following rules.

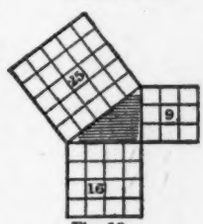


Fig. 10.

To find the hypotenuse. Rule—Add the square of the base and the square of the perpendicular, and of the sum extract square root.

A and B start from the same point, A going 4 miles due west and B, 3 miles due north; how far apart are they then?

$4^2 = 16$
$3^2 = 9$
$\sqrt{25} = 5$

Answer—5 miles.

The square of 4 (base) = 16; of 3 (perpendicular) = 9; the square root of their sum (25) = 5, the hypotenuse.

To find the base or perpendicular. Rule—From the square of the hypotenuse, subtract the square of the other given side, and of their difference extract the square root.

Find the perpendicular of a triangular field whose hypotenuse is 75 rods, base 60 rods. Answer—45 rods.

$75^2 = 5625$
$60^2 = 3600$
$\sqrt{2025} = 45$

Note—To find the difference between the squares of two numbers, simply multiply their sum by their difference.

To find the side of a square equal in area to any given quantity. Rule—Extract the square root of the given quantity.

Thus, the dimensions of a square field containing 4000 square rods must be ($\sqrt{4000} = 63.246$) 63¼ rods, nearly. Proof: $63\frac{1}{4}^2 = 4000 +$

To find the diagonal of a square. Rule—Multiply one side of the square by 10, diminish the product by 1% of itself and divide remainder by 7.

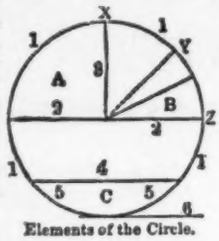
What is the diagonal of a field 35 rods square? This is a simple way of finding the hypotenuse of a triangle whose base and perpendiculars are equal.

$35 \times 10 = 350$,
1% of $350 = 3.5$
$7)346.5$
Ans. (rd.) 49.5

The Circle

A circle is a plane figure bounded by a curved line, (1, 1, 1, 1) called circumference, every point of which is equally distant from

the center. The diameter is a straight line (2, 2) across a circle, through its center. The radius is a straight line (3) from the center to the circumference. An arc is any part of the circumference (5, 5). A chord, a straight line (4) joining ends of an arc. A tangent (6) touches circum. without cutting it. A segment is space (C) enclosed by arc and chord. A sector, space (B) enclosed by two radii and arc. A quadrant (A) is 90° or the fourth part of circle. A circle is divided into 360°; from X to Y is 45°; from X to Z, 90°. A sextant is one-sixth of a circle.



Elements of the Circle.

To find the *circumference* of a circle, the diameter being given. Rule—Multiply the diameter by 3 1/7; for greater accuracy, by 3.1416.

Find circumference of bicycle wheel; diam. 28 in.

Answer—28 × 3 1/7 = 88 in.

To find the *diameter* of a circle, the circumference being given. Rule—Divide the circumference by 3 1/7, or multiply it by .3183.

Circumference of a tree 144½ in., find diam.

Answer—144.5 × 3183 = 46 in.

To find the *area* of a circle. Rule—Multiply the square of the diameter by .7854; or the square of the radius by 3.1416; or the square of the circumference by .07958.

Find the area of a piston 20 in. in diam.

Answer—20^2 × .7854 = 314.16 sq. in.

Over how many sq. ft. can a cow graze, staked to a rope 50 ft. long? Here, 50 feet is the radius.

Answer—50^2 × 3.1416 = 7854 sq. ft.

To find the *radius* of a circle, the area being given. Rule—Multiply the area by .3183 and extract the square root of the product.

Find length of halter, tied to stake, that will enable horse to graze on 1 acre.

Answer—Square feet in acre, 43560 × .3183 = 13865; √13865 = 117¾ ft. long.

Note—The circumference of a circle is 3.1416 times greater than the diameter. The number 3.1416 (called Pi); its reciprocal, .3183; its 4th part .7854, its 6th part .5236, and others, should be committed to memory as they are indispensable factors in computing the areas and volumes of circular figures and bodies.

To find the *area of a sector* of a circle. Rule—Take such a part of the circle as the degrees in the given arc, are part of 360. Thus, a sector whose arc is 40°, contains 40/360 or 1/9 of the area of the circle.

To find the side of the greatest square that can be inscribed in a given circle. Rule—Multiply the diameter of the circle by .707; or the circumference by .225.

The diameter of a log is 24 inches; how large a sill can be cut from it?

24 × .707 = 17 in. square, nearly.

To inscribe the greatest equilateral triangle. Rule—Multiply the diameter of the circle by .886.

Side of greatest inscribed hexagon equals the radius of a circle.

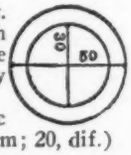
To find the diameter of a circle that will inscribe a given square. Rule—Multiply the side of the desired square by 1.414.

What must be diam. of a log to cut a sill 12 in. sq.?

Answer—12 × 1.414 = 17 in.

The area of the greatest square inscribed in a given circle is exactly ½ of the area of the least square circumscribed about the same circle—or the square of its diameter.

To find the area between the two *concentric circles*. Rule—Take the difference between the area of each circle. A simpler way is to multiply the sum of the two diameters by their difference, and the product by .7854.



Find the area included between two concentric circles whose diameters are 30 and 50 inches. (80, sum; 20, dif.)

Answer—20 × 80 = 1600 × .7854 = 1256.64 sq. in.

To find the diameter of a circle whose area is equal to the area of a given square. Rule—Multiply one side of the given square by 1.1284.

To find the side of a square whose area is equal to the area of a given circle. Rule—Multiply the diameter of the given circle by .8862.

To find the diameter of three greatest equal circles that can be inscribed in a given circle. Rule—Multiply the diameter of the given circle by .464.

Find the diameters of the three greatest circles that can be inscribed in a circle 50 in. in diam.

Answer—50 × .464 = 23.2 in.

An *ellipse* is a plane figure bounded by an oval curved line and has a long and a short diameter or axis.

To find its circumference. Rule—Multiply the sum of the two diameters by 3.1416, and take half of the product.

Ellipse.

Find the circumference of an ellipse whose diameters are .41 and 29 ft.

(41 + 29) = 70 × 3.1416 ÷ 2 = 110 ft. nearly.

To find the *area of an ellipse*. Rule—Multiply the product of the two diameters by .7854.

How many square ft. are there in an elliptical platform whose diameters are 60 and 40 ft.?

60 × 40 = 2400 × .7854 = 1885 sq. ft. nearly.

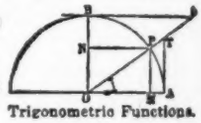
Polygons

To find the area of polygons, having equal sides and equal angles. Rule—Multiply the square of one of the equal sides—of a triangle, by .433; of a pentagon, by 1.7205; of hexagon, by 2.5981; of octagon, by 4.8284.

One side of an equilateral triangle is 30 inches, and of an octagon, 10 in.

Find sq. in. in each.

30^2 × 433 = 389.7 in. T; 10^2 × 4.824 = 482.84 in. O.



Trigonometric Functions.

For the benefit of those who intend to study trigonometry and surveying, this illustration is inserted here. It will be an advantage and saving of time to be already familiar with the terms and the functions of the science when beginning its study.

- P M, sine.
- O M, cosine.
- A T, tangent.
- B S, cotangent.
- O T, secant.
- O S, cosecant.
- M A, versed sine.
- B N, conversed sine.

Cubes, Cones, Pyramids, Spheres,

A *cube* is a solid body, having six equal square sides. To find its area. Rule—Multiply area of one side by 6. To find its volume. Multiply the length, the breadth and the thickness together.

Cube.

Find sq. in. in surface of a 12 in. cube.

Answer—12^2 × 6 = 864.

How many cubic in. in a cubic foot?

Answer—$*12^3$ = 1728.

Find cu. ft. in a cu. mile.

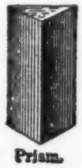
Answer—5280^3 = 147197952000.

A *parallelopiped* is a solid body whose six faces are all rectangles. To find its area. Rule—Add areas of its six sides. To find its volume. Same as the cube. How many cubic feet in a wagon bed 10½ feet long, 3 ft. wide and 1¼ ft. deep?

Parallelopiped.

Answer—10½ × 3 × 1¼ = 39⅜.

A *prism* is a solid having three or more rectangular sides, whose ends or bases are parallel plane figures. To find its area. Rule—Add areas of the sides and ends. To find its volume. Multiply the area of one end by the length.


Prism.

Find the area of a triangular prism, each of whose three sides are 10 by 25 inches.

Answers—836.6 sq. in.

10^2 × .433 × 2 = 86.6 sq. in. in area of the two ends.

10 × 25 × 3 = 750 sq. in. area of sides. 86.0 + 750 = 836.6.

How many cubic inches in above prism, 10 by 25 inches?

Answer—10^3 × .433 = 43.3 × 25 = 1082½ cu. in.

A *globe* or *sphere* is a solid body, bounded by a uniformly curved surface. To find its area. Rule—Multiply the square of diameter by 3.1416; or the square of the circumference by .3183. To find its volume. Multiply the cube of diameter by .5236.

Globe.

How many square in. in the surface; and how many cubic in. in the volume of a globe 12 in. in diameter?

Answer—904.78 cu. in. $12^2 \times 3.1416 = 452.39$ sq. in. $12^3 \times .5236 = 904.78$ cu. in.

How many cubic miles in the earth, its diameter being nearly 8000 miles?

Answer—$2000^3 \times .5236 = 268083200000$ cubic mi.

Find greatest cube inscribed in a 26 in. globe.

Answer—$26 \times .577 = 15$ in.

To find the dimensions of a cube, equivalent in volume to a given globe. Rule—Multiply the diameter of given globe by 806.

To find the diameter of a globe, equivalent in volume to a given cube. Rule—Multiply one side of the cube by 1.2407.

A *cylinder* is a round body of uniform diameter whose ends are parallel plane figures. To find its area. Rule—Multiply the circumference by the length and to the product add the areas of both ends. To find its volume. Multiply the area of one end by length.

Cylinder.

Find the area of a cylinder 30 inches in circumference and 40 inches long.

Answer—1343.24 sq. in.

$30 \times 40 = 1200$ sq. in. in convex surface.

$30^2 \times .07958 \times 2 = 143.24$ sq. in. in the two ends.

Find cubic in. in a cylinder, diameter, 20 in., length 50 in.

Answer—$20^2 \times .7854 \times 50 = 15708$ cu. in.

A *cone* is a solid, which has a circular base and tapers uniformly to a point called vertex.

A *pyramid* is a solid, resembling a cone, having three or more triangular sides.

Cone.

Pyramid.

To find the area of a *cone or pyramid*. Rule—Multiply the circumference or perimeter of the base by the slant height, and to half of the product, add the area of the base.

Find the area or surface of a cone whose circumference at base is 40 in., and slant height 50 in.

Answer—1127.33 sq. in.

$50 \times 40 \div 2 = 1000$ sq. in. in convex surface.

$40^2 \times .07958 = 127.33$ in. base.

To find the volume of a cone or pyramid. Rule—Multiply the area of the base by the height and take ⅓ of the product.

How many cubic feet in a 6 sided pyramid, 10 ft. high, whose perimeter, at base is 15 ft. or each side 2½ ft.?

Answer—54.13 cu. ft.

$2\frac{1}{2}^2 \times 2.598 = 16.24$, area of base. $10 \times 16.24 \div 3 = 54.13$.

Find cu. in. in a cone whose height is 12½ in., and diameter of base 10 in.

Answer—$10^2 \times .7854 = 78.54$ area of base. $78.54 \times 12\frac{1}{2} \div 3 = 32.25$ cu. in.

The solid contents of the cone, globe, cylinder and the cube, all of equal dimensions, are in the ratio of 1, 2, 3 and 3.82 respectively. Thus, taking 1 foot as the height and the diameter; the cone contains .2618; the globe .5236, and the cylinder .7854 of a cubic foot. The cube equals 1 cu. ft.

The *frustum of a cone or pyramid* is the part which remains after cutting off the top, parallel to the plane of the base. To find the area of a frustum. Rule—Multiply the sum of circumferences, or perimeters, by the slant height, and to half of the product, add the area of each base.

Frustums.

Find the *area of a frustum* of a cone, whose slant height is 40 in., its greater circumference, 30 in., and its smaller one, 10 in.

Answer—879.58 sq. in.

$30 + 10 \times 40 \div 2 = 800$, sides. $30^2 + 10^2 \times .07958 = 79.58$, area of bases.

To find the *volume of any frustum*. Rule—Square both ends of one side, if angular, or the diameters of both ends or bases, if round. To the two squares add the product of the given ends or diameters; ⅓ of this sum will be the area of the average base of the frustum of a square pyramid, which multiplied by .7854 equals area of average base of frustum of a cone; multiplied by .433, of a three sided frustum, by 1.7205, of a five sided fr., by 2.5981, of a six sided frustum, by 4.8284, of an eight sided frustum. For volume: multiply average area by perpendicular height.

Find the volume or capacity of a round tank whose diameter is 15 ft. at base, 12 ft. at top, and 10 ft. deep. Ans.—14.37 cu. ft.

$12^2 = 144$ $\quad 15^2 = 225$ $\quad 12 \times 15 = 180$

$183 \times .7854 = 143.73$ sq. ft., area of av. base of Fr. of cone.

$3)549(183$, area of av. base of F. of sq. pyr.

$143.73 \times 10 = 1437.3$ cu. ft. $\times 7.48 = 10751$ gallons.

Find sq. ft. of lumber in a wagon tongue; large end, 4½ in. sq., small end, 2½ in., length, 9 ft. (108 in.).

Answer—$4\frac{1}{2} + 2\frac{1}{2}^2 + (4\frac{1}{2} \times 2\frac{1}{2}) \div 3 = 12\ 7/12$ sq. in., area of average base; $12\ 7/12 \times 108 = 1359$ cu. in. $\div 144 = 9\ 7/16$ sq. ft.

How many cu. ft. in a straight log, whose diameter at large end is 3 ft., small end, 2 ft., length 12 ft?

Answer—$3^2 + 2^2 + (3 \times 2) \div 3 \times .7854 = 4.974$ sq. ft., area of average base; $4.974 \times 12 = 59.69$ cu. ft.

A *spheroid* or elongated globe has a fixed and a revolving axis. To find its area. Rule—Multiply the revolving axis by the fixed axis, and that product by 3.1416. To find its volume. Rule—Multiply the square of the revolving axis by the fixed axis and that product by .5236. Find area, also the volume of spheroid; revolving axis, 20 in., fixed, 30 in.

Spheroid

$20 \times 30 \times 3.1416 = 1884.96$ sq. in. in area.

$20^2 \times 30 \times .5236 = 6283.2$ cu. in. in volume.

A *cylindrical ring* is formed by bending a cylinder. To find its area. Rule—Multiply sum of inside diam. and thickness of ring, by thickness, and the product by 9.87. To find its volume. Rule—Multiply sum of inside diam. and thickness, by square of thickness, and product by 2.467.

Ring.

Find the area, also the volume of a ring whose inner diameter is 15 inches, and whose thickness is 5 inches.

$(15 + 5) \times 5 \times 9.87 = 987$ sq. in. in area. $(15 + 5) \times 5^2 \times 2.467 = 1233.5$ cu. in vol.

To find the dimensions of *greatest cube that can be inscribed in a given globe*. Rule—Multiply the diameter of the globe by .577.

The above material has been drawn from "Ropp's Calculator"—an extremely useful and inexpensive little booklet published by C. Ropp & Sons, of Chicago.

CONVERSION FACTORS FOR ENGINEERS*

The word gallon, used in any conversion factor, designates the U. S. gallon. Likewise, the word ton designates a short ton, 2,000 pounds.

The figures 10^{-1}, 10^{-2}, 10^{-3}, etc., denote 0.1, 0.01, 0.001, etc., respectively.

The figures 10^{1}, 10^{2}, 10^{3}, etc., denote 10, 100, 1000, etc.. respectively.

"Parts Per Million," (designated as p.p.m.), is always by weight. As used in the sanitary field, p.p.m. represents the number of pounds of dry solids contained in one million pounds of water. In this field, one part per million may be expressed as 8.345 pounds of dry solids to one million U. S. gallons of water.

Multiply	By	To Obtain
Acres	43,560	Square feet
"	4047	Square meters
Acre-feet	43,560	Cubic feet
" "	325,851	Gallons
" "	1233.49	Cubic meters
Atmospheres	29.92	Inches of mercury
"	33.90	Feet of water
"	76.0	Cms. of mercury
"	14.70	Lbs./sq. inch
Barrels cement	376	Pounds—cement
Bags or sacks-cement	94	Pounds— "
British Thermal Units	777.5	Foot-lbs.
" " "	3.927×10^{-4}	Horse-power-hrs.
" " "	2.928×10^{-4}	Kilowatt-hrs.
" " "	0.2520	Kilogram-calories
" " "	107.5	Kilogram-meters
B.T.U./min.	12.96	Foot-lbs./sec.
" "	0.02356	Horse-power
" "	0.01757	Kilowatts
Centimeters	0.3937	Inches
Centimeters of mercury	0.01316	Atmospheres
" " "	0.4461	Feet of water
" " "	27.85	Lbs./sq. ft.
" " "	0.1934	Lbs./sq. inch
Centimeters/second	1.969	Feet/min.
" "	0.03281	Feet/sec.
" "	0.6	Meters/min.
Cubic centimeters	3.531×10^{-5}	Cubic feet
" "	6.102×10^{-2}	Cubic inches
" "	2.642×10^{-4}	Gallons
" "	10^{-6}	Cubic meters
" "	10^{-3}	Liters
Cubic feet	7.48052	Gallons
" "	1728	Cubic inches
" "	0.03704	Cubic yards
" "	28.32	Liters
" "	2.832×10^{4}	Cubic cms.
" "	0.02832	Cubic meters
Cubic feet/second	0.646317	Million gals./day
" " "	448.831	Gallons/min.
Cubic inches	16.39	Cubic centimeters
" "	5.787×10^{-4}	Cubic feet
" "	1.639×10^{-5}	Cubic meters
" "	4.329×10^{-3}	Gallons
" "	1.639×10^{-2}	Liters
Cubic meters	35.31	Cubic feet
" "	1.308	Cubic yards
" "	264.2	Gallons
" "	10^{3}	Liters
Cubic yards	27	Cubic feet
" "	46.656	Cubic inches
" "	0.7646	Cubic meters
" "	202.0	Gallons
" "	764.6	Liters
Drams	27.34375	Grains
"	0.0625	Ounces
"	1.771845	Grams
Fathoms	6	Feet
Feet	30.48	Centimeters
"	0.3048	Meters
Feet of water	0.8826	Inches of mercury
" " "	0.4335	Lbs./sq. inch
" " "	62.43	Lbs./sq. ft.
" " "	0.02950	Atmospheres
" " "	304.8	Kgs./sq. meter
Feet/sec.	30.48	Centimeters/sec.
" "	18.29	Meters/min.
Foot-pounds	1.286×10^{-3}	British thermal units
" "	5.050×10^{-7}	Horse-power-hrs.
" "	0.1383	Kilogram-meters
" "	3.766×10^{-7}	Kilowatt-hrs.
Foot-pounds/min.	3.030×10^{-5}	Horse-power
" " "	2.260×10^{-5}	Kilowatts
Gallons	0.1337	Cubic feet
"	231	Cubic inches
"	3785	Cubic centimeters
"	3.785×10^{-3}	Cubic meters
"	3.785	Liters
Gallons, Imperial	1.200095	U. S. gallons
" U. S.	0.83267	Imperial gallons
Gallons water	8.3453	Pounds of water
Gallons/min.	2.228×10^{-3}	Cubic feet/sec.
" "	0.06308	Liters/sec.
" "	8.0208	Cu. ft./hr.
Grains (troy)	1	Grains (avoir.)
"	0.06480	Grams
Grains/U.S. gal.	17.118	Parts/million
" /U.S. gal.	142.86	Lbs./million gal.
" /Imp. gal.	14.254	Parts/million
Grams	15.43	Grains
"	0.03527	Ounces
"	980.7	Dynes
Grams/liter	58.417	Grains/gal.
" "	8.345	Pounds/1000 gals.
" "	1000	Parts/million
Hectares	2.471	Acres
Horse-power	42.44	B.T. Units/min.
" "	550	Foot-lbs./sec.
" "	0.7457	Kilowatts
Horse-power (boiler)	33,479	B.T.U./hr.
" " "	9.803	Kilowatts
Inches	2.540	Centimeters
Inches of mercury	1.133	Feet of water
" " "	0.4912	Lbs./sq. inch
" " "	0.03342	Atmospheres
" " "	345.3	Kgs./sq. meter
Inches of water	0.07355	Inches of mercury
" " "	0.03613	Lbs./sq. inch
Kilograms	2.205	Lbs.
Kilograms-calories/min.	51.43	Foot-pounds/sec.
" " "	0.09351	Horse-power
" " "	0.06972	Kilowatts
Kgs./sq. meter	3.281×10^{-3}	Feet of water
" " "	1.422×10^{-3}	Lbs./sq. inch
Kilometers	3281	Feet
"	0.6214	Miles
Kilometers/hr.	0.9113	Feet/sec.
" "	27.78	Centimeters/sec.
Kilowatts	56.92	B.T. Units/min.
"	737.6	Foot-lbs./sec.
"	1.341	Horse-power
"	14.34	Kg.-calories/min.
Liters	0.2642	Gallons
"	61.02	Cubic inches
"	0.03531	Cubic feet
Meters	3.281	Feet
"	39.37	Inches
"	1.094	Yards
Miles	5280	Feet
"	1.609	Kilometers
Miles/min.	88	Feet/sec.
" "	1.609	Kilometers/min.
Milligrams/liter	1	Parts/million
Million gals./day	1.54723	Cubic ft./sec.
Miner's inches	1.5	Cubic ft./min.
Ounces	28.349527	Grams
"	437.5	Grains
"	0.9115	Ounces (troy)
Ounces (fluid)	1.805	Cubic inches
" "	29.57	Cubic cm.
Parts/million	8.345	Lbs./million gal.
" "	0.0584	Grains/U. S. gal.
" "	0.07016	Grains/Imp. gal.
Pounds	16	Ounces
"	7000	Grains
"	453.5924	Grams
"	1.21528	Pounds (troy)

*Selections from a booklet of—"Conversion Factors for Engineers"—distributed by The Dorr Co., New York City.

Multiply	By	To Obtain
Pounds of water	0.01602	Cubic feet
" " "	27.68	Cubic inches
" " "	0.1198	Gallons
Pounds/cubic foot	0.01602	Grams/cubic cm.
" " "	16.02	Kgs./cubic meter
" " "	5.787×10^{-4}	Lbs./cubic inch
Pounds/foot	1.488	Kgs./meter
Pounds/inch	178.6	Grams/cm.
Pounds/sq. foot	0.01602	Feet of water
" " "	4.883	Kgs./sq. meter
Pounds/sq. inch	2.307	Feet of water
" " "	2.036	Inches of mercury
" " "	0.06804	Atmospheres
" " "	703.1	Kgs./sq. meter
Quires	25	Sheets
Reams	500	Sheets
Square centimeters	0.1550	Square inches
" "	1.076×10^{-3}	Square feet
Square feet	144	Square inches
" "	0.09290	Square meters
" "	2.296×10^{-5}	Acres
Square inches	6.452	Square centimeters

Multiply	By	To Obtain
Square kilometers	247.1	Acres
" "	10.76×10^{6}	Square feet
" "	1.196×10^{6}	Square yards
Square meters	10.76	Square feet
" "	1.196	Square yards
Square miles	640	Acres
" "	27.88×10^{6}	Square feet
" "	2.590	Square Kilometers
Square yards	9	Square feet
" "	0.8361	Square meters
" "	2.066×10^{-4}	Acres
Tons (long)	1016	Kilograms
" "	2240	Pounds
" "	1.12000	Tons (short)
Tons (metric)	10^{3}	Kilograms
" "	2205	Pounds
Tons (short)	2000	Pounds
" "	907.18486	Kilograms
Tons of water/24 hrs.	0.16643	Gallons/min.
Watts	0.05692	B.T.Units/min.
"	0.7376	Foot-pounds/sec.
"	1.341×10^{-3}	Horse-power
"	0.01434	Kg.-calories/min.
Yards	0.9144	Meters

Relative Carrying Capacities of Pipe Lines of Equal Smoothness

Prepared by Emil L. Neubling for the Reading Meter Repair Co.

Diameter of Pipes	⅛	¼	⅜	½	¾	1	1¼	1½	2	2½
26										348.81
24										285.55
22										229.20
20									316.23	181.02
18									243.00	139.10
16								371.60	181.02	103.62
15								316.23	154.05	88.18
14							419.80	266.13	129.64	74.21
12							285.55	181.02	88.18	50.48
10						316.23	181.02	114.76	55.90	32.00
9						243.00	139.10	88.18	42.96	24.65
8					371.60	181.02	103.62	65.69	32.00	18.32
7					266.13	129.64	74.21	47.05	22.92	13.12
6					181.02	88.18	50.48	32.00	15.59	8.92
5				316.23	114.76	55.90	32.00	20.29	9.88	5.66
4½				243.00	88.18	42.96	24.65	15.59	7.59	4.35
4			371.60	181.02	65.69	32.00	18.32	11.61	5.66	3.24
3½			266.13	129.64	47.05	22.92	13.12	8.32	4.05	2.32
3			181.02	88.18	32.00	15.59	8.92	5.66	2.76	1.58
2½		316.23	114.76	55.90	20.29	9.88	5.66	3.59	1.75	1.00
2		181.02	65.69	32.00	11.61	5.66	3.24	2.05	1.00	
1½		88.18	32.00	15.59	5.66	2.76	1.58	1.00		
1¼	316.23	55.90	20.29	9.88	3.59	1.75	1.00			
1	181.02	32.00	11.61	5.66	2.05	1.00				
¾	88.18	15.59	5.66	2.05	1.00					
½	32.00	5.66	2.05	1.00						
⅜	15.59	2.76	1.00							
¼	5.66	1.00								
⅛	1.00									

Diameter of Pipes	3	3½	4	4½	5	6	7	8	9	10
48			498.83	371.60	285.55	181.02	123.13	88.18	65.69	50.48
46			448.48	334.09	256.73	162.75	110.70	79.10	59.06	45.38
44			401.31	298.96	229.20	145.63	99.29	70.94	52.85	40.61
42			357.25	243.00	204.50	129.64	88.18	63.15	47.05	36.15
40			316.23	235.57	181.02	114.76	78.06	55.90	41.64	32.00
38		388.41	278.17	207.22	159.23	100.94	68.66	49.17	36.63	28.15
36		339.30	243.00	181.02	139.10	88.18	59.98	42.96	32.00	24.65
34		294.12	210.64	156.92	120.58	76.44	51.99	37.24	27.74	21.32
32		252.76	181.02	134.85	103.62	65.69	44.68	32.00	23.84	18.32
30	316.23	215.10	154.05	114.76	88.18	55.90	38.02	27.23	20.29	15.59
28	266.13	181.02	129.64	96.57	74.21	47.05	32.00	22.92	17.07	13.12
26	221.12	150.41	107.72	80.24	61.66	39.09	26.59	19.04	14.18	10.90
24	181.02	123.13	88.18	65.69	50.48	32.00	21.77	15.59	11.61	8.92
22	145.63	99.29	70.94	52.85	40.61	25.74	17.51	12.54	9.34	7.18
20	114.76	78.06	55.90	41.64	32.00	20.29	13.80	9.88	7.36	5.66
18	88.18	59.98	42.96	32.00	24.65	15.59	10.60	7.59	5.66	4.35
16	65.69	44.68	32.00	23.84	18.32	11.61	7.90	5.66	4.21	3.24
15	55.90	38.02	27.23	20.29	15.59	9.88	6.72	4.81	3.59	2.76
14	47.05	32.00	22.92	17.07	13.12	8.32	5.66	4.05	3.02	2.32
12	32.00	21.77	15.59	11.61	8.92	5.66	3.85	2.76	2.05	1.58
10	20.29	13.80	9.88	7.36	5.66	3.59	2.44	1.75	1.30	1.00
9	15.59	10.60	7.59	5.66	4.35	2.76	1.83	1.34	1.00	
8	11.61	7.90	5.66	4.21	3.24	2.05	1.40	1.00		
7	8.32	5.66	4.05	3.02	2.32	1.47	1.00			
6	5.66	3.85	2.76	2.05	1.58	1.00				
5	3.59	2.44	1.77	1.30	1.00					
4½	2.76	1.83	1.34	1.00						
4	2.05	1.40	1.00							
3½	1.47	1.00								
3	1.00									

Diameter of Pipes	12	14	15	16	18	20	22	24	26	28
48	32.00	21.77	18.32	15.59	11.61	8.92	7.03	5.66	4.63	3.85
46	28.77	19.57	16.47	14.02	10.44	8.02	6.32	5.09	4.16	3.46
44	25.74	17.51	14.71	12.54	9.34	7.18	5.66	4.55	3.73	3.10
42	22.92	15.59	13.12	11.16	8.32	6.39	5.04	4.05	3.32	2.76
40	20.29	13.80	11.61	9.88	7.36	5.66	4.46	3.59	2.94	2.44
38	17.84	12.14	10.21	8.69	6.48	4.98	3.92	3.15	2.58	2.17
36	15.59	10.60	8.92	7.59	5.66	4.35	3.43	2.76	2.26	1.83
34	13.51	9.19	7.74	6.58	4.90	3.77	2.97	2.39	1.96	1.62
32	11.61	7.90	6.65	5.66	4.21	3.24	2.55	2.05	1.68	1.40
30	9.88	6.72	5.66	4.81	3.59	2.76	2.17	1.75	1.43	1.19
28	8.32	5.66	4.76	4.05	3.02	2.32	1.83	1.47	1.20	1.00
26	6.91	4.70	3.96	3.37	2.51	1.93	1.52	1.22	1.00	
24	5.66	3.85	3.24	2.76	2.05	1.58	1.24	1.00		
22	4.55	3.10	2.61	2.22	1.65	1.27	1.00			
20	3.59	2.44	2.05	1.75	1.30	1.00				
18	2.76	1.83	1.58	1.34	1.00					
16	2.05	1.40	1.18	1.00						
15	1.75	1.19	1.00							
14	1.47	1.00								
12	1.00									

Diameter of Pipes	30	32	34	36	38	40	42	44	46	48
48	3.24	2.76	2.37	2.05	1.80	1.58	1.40	1.24	1.11	1.00
46	2.91	2.48	2.13	1.85	1.61	1.42	1.26	1.12	1.00	
44	2.61	2.22	1.91	1.65	1.44	1.27	1.12	1.00		
42	2.32	1.97	1.70	1.47	1.28	1.13	1.00			
40	2.05	1.75	1.50	1.30	1.14	1.00				
38	1.81	1.54	1.32	1.14	1.00					
36	1.58	1.34	1.15	1.00						
34	1.37	1.16	1.00							
32	1.18	1.00								
30	1.00									

The foregoing tables will be found useful in proportioning distribution lines.

Example: To find how many one-half inch pipes can be supplied by a 4-in. line, follow down the ½-in. vertical column to the number opposite 4-in. diameter of the first column, where the number 181.02 is found, which is the number of one-half inch lines that can be supplied by a 4-in. line.

Example: To find how many 12-in. lines can be supplied by a 48-in. line, follow horizontally along the 48-in. diameter of the first column, until you reach the 12-in. vertical column, where the number 32 is found, which is the result desired.

AREAS OF CIRCLES—SQUARES—SQUARE ROOTS

(Also Fractions to Decimal Equivalent.)

—Number— Fraction	Decimal	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
1/16	.0625	.0039	.2500	.0031
1/8	.125	.0156	.3536	.0125
3/16	.1875	.0352	.4330	.0276
1/4	.25	.0625	.5000	.0491
5/16	.3125	.0977	.5590	.0767
3/8	.375	.1406	.6124	.1105
7/16	.4375	.1914	.6614	.1503
1/2	.50	.2500	.7071	.1964
9/16	.5625	.3164	.7500	.2485
5/8	.625	.3906	.7906	.3068
11/16	.6875	.4727	.8297	.3712
3/4	.75	.5625	.8660	.4418
13/16	.8125	.6602	.9014	.5185
7/8	.875	.7656	.9354	.6013
15/16	.9375	.8789	.9683	.6903
1	1.	1.000	1.000	.7854
1 1/8	1.125	1.266	1.061	.9940
1 1/4	1.25	1.563	1.118	1.227
1 3/8	1.375	1.891	1.175	1.485
1 1/2	1.50	2.250	1.225	1.767
1 5/8	1.625	2.641	1.275	2.074
1 3/4	1.75	3.063	1.323	2.405
1 7/8	1.875	3.516	1.369	2.761
2	2.	4.000	1.414	3.142
2 1/8	2.125	4.516	1.458	3.547
2 1/4	2.25	5.063	1.500	3.976
2 3/8	2.375	5.641	1.541	4.430
2 1/2	2.50	6.250	1.581	4.909
2 5/8	2.625	6.891	1.620	5.412
2 3/4	2.75	7.563	1.658	5.940
2 7/8	2.875	8.266	1.696	6.492
3	3.	9.000	1.732	7.069
3 1/8	3.125	9.766	1.768	7.670
3 1/4	3.25	10.56	1.803	8.296
3 3/8	3.375	11.39	1.837	8.946
3 1/2	3.50	12.25	1.871	9.621
3 5/8	3.625	13.14	1.904	10.32
3 3/4	3.75	14.06	1.937	11.04
3 7/8	3.875	15.02	1.969	11.79
4	4.	16.00	2.000	12.57
4 1/8	4.125	17.02	2.031	13.36
4 1/4	4.25	18.06	2.062	14.19
4 3/8	4.375	19.14	2.092	15.03
4 1/2	4.50	20.25	2.121	15.90
4 5/8	4.625	21.39	2.151	16.80
4 3/4	4.73	22.56	2.180	17.72
4 7/8	4.875	23.77	2.208	18.67
5	5.00	25.00	2.236	19.64
5 1/4	5.25	27.56	2.291	21.65
5 1/2	5.50	30.25	2.345	23.76
5 3/4	5.75	33.06	2.398	25.97
6	6.	36.00	2.450	28.27
6 1/4	6.25	39.06	2.500	30.68
6 1/2	6.50	42.25	2.550	33.18
6 3/4	6.75	45.56	2.598	35.78
7	7.	49.00	2.646	38.48
7 1/4	7.25	52.56	2.693	41.28
7 1/2	7.50	56.25	2.739	44.18
7 3/4	7.75	60.06	2.784	47.17
8	8.00	64.00	2.828	50.27
8 1/4	8.25	68.06	2.872	53.46
8 1/2	8.50	72.25	2.916	56.75
8 3/4	8.75	76.56	2.958	60.13
9	9.00	81.00	3.000	63.62
9 1/4	9.25	85.56	3.041	67.20
9 1/2	9.50	90.25	3.082	70.88
9 3/4	9.75	95.06	3.123	74.66
10	10.0	100	3.162	95.03
..	....	....	....	....
..	....	....	....	....
10	....	100	3.162	78.54
11	....	121	3.317	95.03
12	....	144	3.464	113.1
13	....	169	3.606	132.7
14	....	196	3.742	153.9
15	....	225	3.873	176.7
16	....	256	4.000	201.1
17	....	289	4.123	227.0
18	....	324	4.243	254.5
19	....	361	4.359	283.5
20	....	400	4.472	314.2
21	....	441	4.583	346.4
22	....	484	4.690	380.1
23	....	529	4.796	415.5
24	....	576	4.899	452.4
25	....	625	5.000	490.9
26	....	676	5.099	530.9
27	....	729	5.196	572.6
28	....	784	5.292	615.8
29	....	841	5.385	660.5
30	....	900	5.477	706.9
..	....	...	....	....
..	....	...	....	....

No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
31	961	5.568	754.8
32	1024	5.657	804.2
33	1089	5.745	855.3
34	1156	5.831	907.9
35	1225	5.916	962.1
36	1296	6.000	1017.9
37	1369	6.083	1075.2
38	1444	6.164	1134.1
39	1521	6.245	1194.6
40	1600	6.325	1256.7
41	1681	6.403	1320.3
42	1764	6.481	1385.4
43	1849	6.557	1452.2
44	1936	6.633	1520.5
45	2025	6.708	1590.4
46	2116	6.782	1661.9
47	2209	6.856	1734.9
48	2304	6.928	1809.6
49	2401	7.000	1885.7
50	2500	7.071	1936.5
51	2601	7.141	2042.8
52	2704	7.211	2123.7
53	2809	7.280	2206.2
54	2916	7.349	2290.2
55	3025	7.416	2375.8
56	3136	7.483	2463.0
57	3249	7.500	2551.8
58	3364	7.616	2642.1
59	3481	7.681	2734.0
60	3600	7.746	2827.4
61	3721	7.810	2922.5
62	3844	7.874	3019.1
63	3969	7.937	3117.2
64	4096	8.000	3217.0
65	4225	8.062	3318.3
66	4356	8.124	3421.2
67	4489	8.185	3525.7
68	4624	8.246	3631.7
69	4761	8.307	3739.3
70	4900	8.367	3848.5
71	5041	8.426	3959.2
72	5184	8.485	4071.5
73	5329	8.544	4185.4
74	5476	8.602	4300.8
75	5625	8.660	4417.9
76	5776	8.718	4536.5
77	5929	8.775	4656.6
78	6084	8.832	4778.4
79	6241	8.888	4901.7
80	6400	8.944	5026.5
81	6561	9.000	5153.0
82	6724	9.055	5281.0
83	6889	9.110	5410.6
84	7056	9.165	5541.8
85	7225	9.220	5674.5
86	7396	9.274	5808.8
87	7569	9.327	5944.7
88	7744	9.381	6082.1
89	7921	9.434	6221.1
90	8100	9.487	6361.7
91	8281	9.539	6503.9
92	8464	9.592	6647.6
93	8649	9.644	6792.9
94	8836	9.695	6939.8
95	9025	9.747	7088.2
96	9216	9.798	7238.2
97	9409	9.849	7389.8
98	9604	9.900	7543.0
99	9801	9.950	7697.7
100	10000	10.00	7854.0
101	10201	10.05	8011.9
102	10404	10.10	8171.3
103	10609	10.15	8332.3
104	10816	10.20	8494.9
105	11025	10.25	8659.0
106	11236	10.30	8824.7
107	11449	10.34	8992.0
108	11664	10.39	9160.9
109	11881	10.44	9331.3
110	12100	10.49	9503.3
111	12321	10.54	9676.9
112	12544	10.58	9852.0
113	12769	10.63	10029
114	12996	10.68	10207
115	13225	10.72	10387
116	13456	10.77	10568
117	13689	10.82	10751
118	13924	10.86	10936
119	14161	10.91	11122
120	14400	10.95	11310
121	14641	11.00	11499
122	14884	11.05	11690
123	15129	11.09	11882
124	15376	11.14	12076
125	15625	11.18	12272
126	15876	11.23	12469
127	16129	11.27	12668
128	16384	11.31	12868
129	16641	11.36	13070
130	16900	11.40	13273
131	17161	11.45	13478
132	17424	11.49	13685
133	17689	11.53	13893
134	17956	11.58	14103
135	18225	11.62	14314
136	18496	11.66	14527
137	18769	11.70	14741
138	19044	11.75	14957
139	19321	11.79	15175
140	19600	11.83	15394
141	19881	11.87	15615
142	20164	11.92	15837
143	20449	11.96	16061
144	20736	12.00	16286
145	21025	12.04	16583
146	21316	12.08	16742
147	21609	12.12	16972
148	21904	12.17	17203
149	22201	12.22	17437
150	22500	12.25	17671
151	22801	12.29	17908
152	23104	12.33	18146
153	23409	12.37	18385
154	23716	12.41	18627
155	24025	12.45	18869
156	24336	12.49	19113
157	24649	12.53	19359
158	24964	12.57	19607
159	25281	12.61	19856
160	25600	12.65	20106
161	25921	12.69	20358
162	26244	12.73	20613
163	26569	12.77	20867
164	26896	12.81	21124
165	27225	12.85	21382
166	27556	12.88	21642
167	27889	12.92	21904
168	28224	12.96	22168
169	28561	13.00	22432
170	28900	13.04	22698
171	29241	13.08	22966
172	29584	13.11	23235
173	29929	13.15	23506
174	30276	13.19	23779
175	30625	13.23	24053
176	30976	13.27	24328
177	31329	13.30	24606
178	31684	13.34	24885
179	32041	13.38	25165
180	32400	13.42	25447
181	32761	13.45	25730
182	33124	13.49	26016
183	33489	13.53	26302
184	33856	13.56	26590
185	34225	13.60	26880
186	34596	13.64	27172
187	34969	13.67	27465
188	35344	13.71	27759
189	35721	13.75	28055
190	36100	13.78	28353
191	36481	13.82	28652
192	36864	13.86	28953
193	37249	13.89	29255
194	37636	13.93	29559
195	38025	13.96	29865
196	38416	14.00	30172
197	38809	14.04	30481
198	39204	14.07	30791
199	39601	14.11	31103
200	40000	14.14	31416
...	.....	....	.....
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...	.....	....	.....
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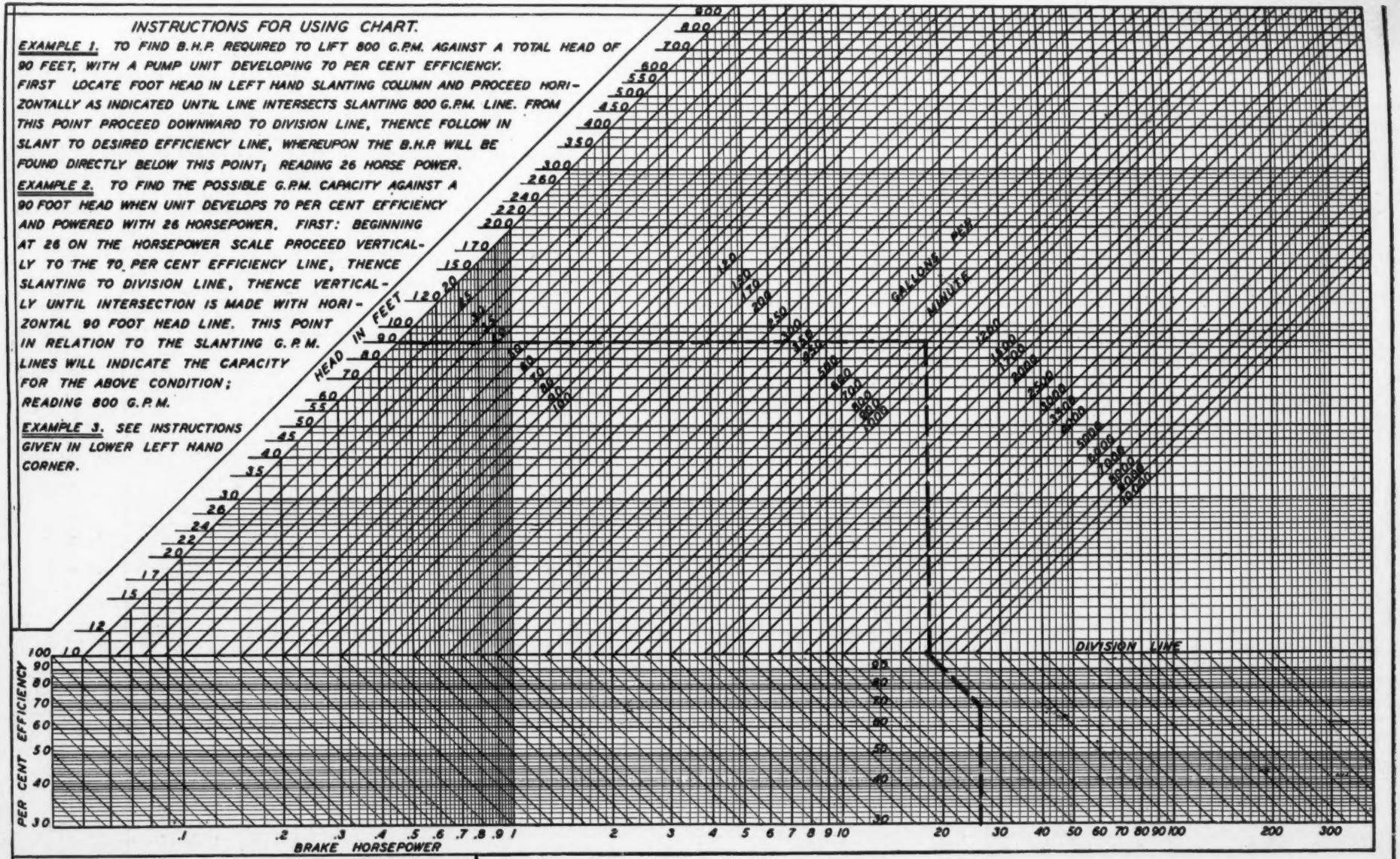

INSTRUCTIONS FOR USING CHART.
EXAMPLE 1. TO FIND B.H.P. REQUIRED TO LIFT 800 G.P.M. AGAINST A TOTAL HEAD OF 90 FEET, WITH A PUMP UNIT DEVELOPING 70 PER CENT EFFICIENCY. FIRST LOCATE FOOT HEAD IN LEFT HAND SLANTING COLUMN AND PROCEED HORIZONTALLY AS INDICATED UNTIL LINE INTERSECTS SLANTING 800 G.P.M. LINE. FROM THIS POINT PROCEED DOWNWARD TO DIVISION LINE, THENCE FOLLOW IN SLANT TO DESIRED EFFICIENCY LINE, WHEREUPON THE B.H.P. WILL BE FOUND DIRECTLY BELOW THIS POINT; READING 26 HORSE POWER.
EXAMPLE 2. TO FIND THE POSSIBLE G.P.M. CAPACITY AGAINST A 90 FOOT HEAD WHEN UNIT DEVELOPS 70 PER CENT EFFICIENCY AND POWERED WITH 26 HORSEPOWER. FIRST: BEGINNING AT 26 ON THE HORSEPOWER SCALE PROCEED VERTICALLY TO THE 70 PER CENT EFFICIENCY LINE, THENCE SLANTING TO DIVISION LINE, THENCE VERTICALLY UNTIL INTERSECTION IS MADE WITH HORIZONTAL 90 FOOT HEAD LINE. THIS POINT IN RELATION TO THE SLANTING G.P.M. LINES WILL INDICATE THE CAPACITY FOR THE ABOVE CONDITION; READING 800 G.P.M.
EXAMPLE 3. SEE INSTRUCTIONS GIVEN IN LOWER LEFT HAND CORNER.
HEAD IN FEET
GALLONS PER MINUTE
DIVISION LINE
PER CENT EFFICIENCY
BRAKE HORSEPOWER
EXAMPLE 3. TO FIND THE EFFICIENCY A PUMP MUST DEVELOP IN ORDER TO DELIVER 800 G.P.M. AGAINST A 90 FOOT HEAD WITH 26 HORSEPOWER. PROCEED AS IN EXAMPLE 1 TO DIVISION LINE, THEN SLANTWISE UNTIL INTERSECTION IS MADE WITH THE VERTICAL 26 HORSEPOWER LINE. THIS POINT WILL LOCATE THE HORIZONTAL EFFICIENCY LINE; READING 70 PER CENT.

Chart for Determining Head, Capacity, Efficiency, Horse Power With Any Three Conditions Known

(From the Peerless Pump Bulletin)

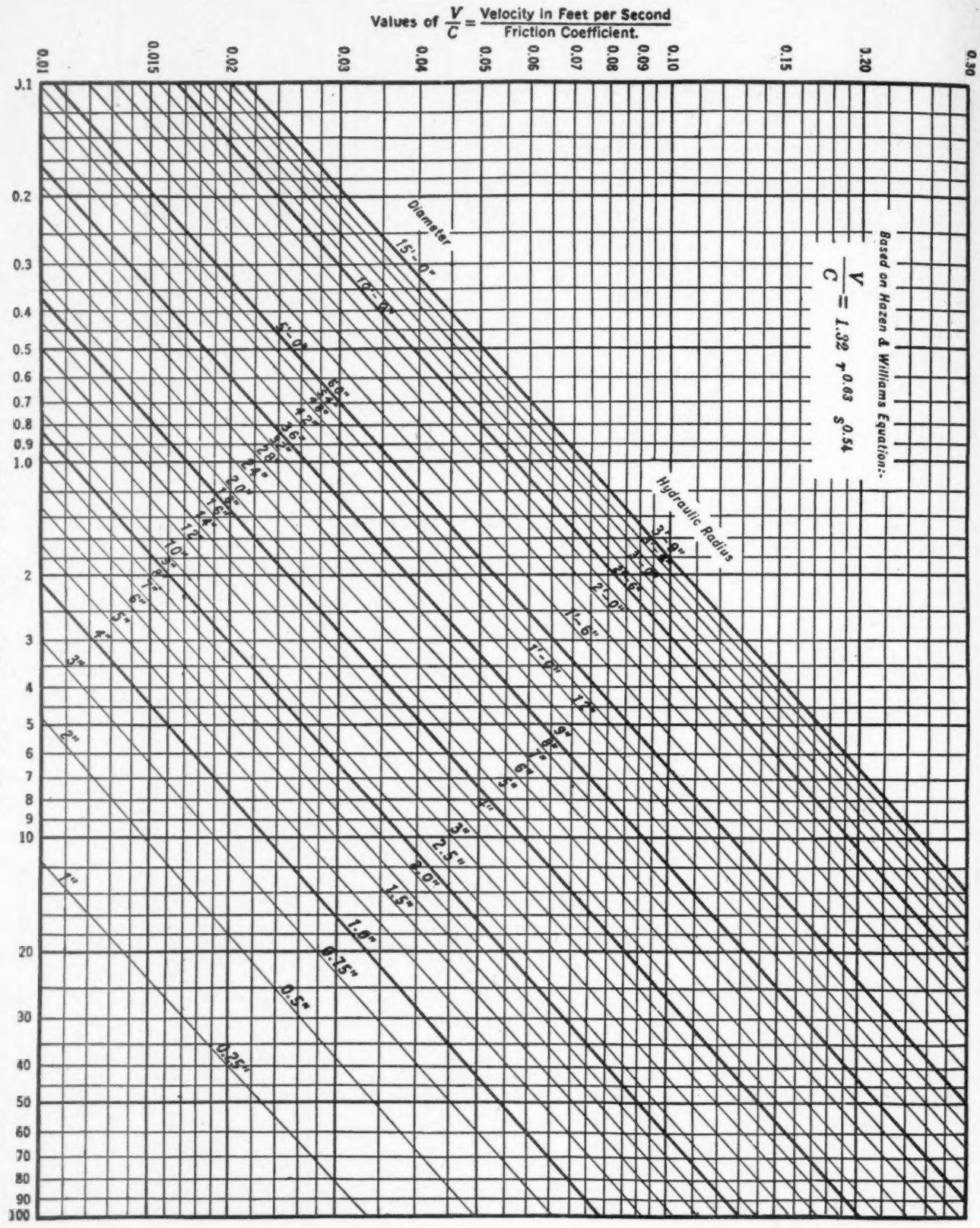


CHART OF LOSS OF HEAD IN FEET PER 1000 FT. OF PIPE

From "Hydro-Electric Handbook"—John Wiley & Sons

Cylindrical Tank Capacities Per Foot of Depth

(The Cubic Foot Figure Is Also the Area in Each Instance)

Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.
1	0.785	5.87	9	63.62	475.9	20	314.2	2350	32	804.3	6016	58	2642	19760
1-3	1.227	9.18	9-6	70.88	530.2	20-6	330.1	2469	33	855.3	6398	60	2827	21150
1-6	1.767	13.22	10	78.54	587.5	21	346.4	2591	34	907.9	6792	62	3019	22580
1-9	2.405	17.99	10-6	86.59	647.7	21-6	363.1	2716	35	962.1	7197	64	3217	24060
2	3.142	23.50	11	95.03	710.9	22	380.1	2844	36	1018	7616	66	3421	25590
2-3	3.976	29.74	11-6	103.9	777.0	22-6	397.6	2974	37	1075	8043	68	3632	27170
2-6	4.909	36.72	12	113.1	846.0	23	415.5	3108	38	1134	8483	70	3848	28790
2-9	5.940	44.43	12-6	122.7	918.0	23-6	433.7	3245	39	1195	8940	72	4072	30450
3	7.069	52.88	13	132.7	992.9	24	452.4	3384	40	1257	9404	74	4301	32170
3-3	8.296	62.06	13-6	143.1	1071	24-6	471.4	3527	41	1320	9876	76	4536	33930
3-6	9.621	71.97	14	153.9	1152	25	490.9	3672	42	1385	10360	78	4778	35740
3-9	11.04	82.62	14-6	165.1	1235	25-6	510.7	3820	43	1452	10860	80	5027	37600
4	12.57	94.00	15	176.7	1322	26	530.9	3972	44	1521	11370	82	5281	39500
4-6	15.90	119.0	15-6	188.7	1412	26-6	551.5	4126	45	1590	11900	84	5542	41450
5	19.63	146.9	16	201.1	1504	27	572.6	4283	46	1662	12430	86	5809	43450
5-6	23.76	177.7	16-6	213.8	1600	27-6	594.0	4443	47	1735	12980	88	6082	45490
6	28.27	211.5	17	227.0	1698	28	615.8	4606	48	1810	13540	90	6362	47590
6-6	33.18	248.2	17-6	240.5	1799	28-6	637.9	4772	49	1886	14110	92	6648	49720
7	38.48	287.9	18	254.5	1904	29	660.5	4941	50	1964	14690	94	6940	51920
7-6	44.18	330.5	18-6	268.8	2011	29-6	683.5	5113	52	2124	15890	96	7238	54140
8	50.27	376.0	19	283.5	2121	30	706.9	5288	54	2290	17130	98	7543	56420
8-6	56.75	424.5	19-6	298.6	2234	31	754.8	5646	56	2463	18420	100	7854	58750

WATER PRESSURE

Feet of Head ⇄ Pressure

Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.
1	0.43	54	23.39	107	46.34	160	69.31	213	92.20	285	123.45
2	0.86	55	23.82	108	46.78	161	69.74	214	92.69	290	125.62
3	1.30	56	24.26	109	47.21	162	70.17	215	93.13	295	127.78
4	1.73	57	24.69	110	47.64	163	70.61	216	93.56	300	129.95
5	2.16	58	25.12	111	48.08	164	71.04	217	92.99	305	132.12
6	2 59	59	25.55	112	48.51	165	71.47	218	94.43	310	134.28
7	3.03	60	25.99	113	48.94	166	71.91	219	94.86	315	136.46
8	3.46	61	26.42	114	49.38	167	72.34	220	95.30	320	138.62
9	3.89	62	26.85	115	49.81	168	72.77	221	95.73	325	140.79
10	4.33	63	27.29	116	50.24	169	73.20	222	96.16	330	142.95
11	4.76	64	27.72	117	50.68	170	73.64	223	96.60	335	145.12
12	5.20	65	28.15	118	51.11	171	74.07	224	97.03	340	147.28
13	5.63	66	28.58	119	51.54	172	74.50	225	97.46	345	149.45
14	6.06	67	29.02	120	51.98	173	74.94	226	97.90	350	151.61
15	6.49	68	29.45	121	52.41	174	75.37	227	98.33	355	153.78
16	6.93	69	29.88	122	52.84	175	75.80	228	98.76	360	155.94
17	7.36	70	30.32	123	53.28	176	76.23	229	99.20	365	158.10
18	7.79	71	30.75	124	53.71	177	76.67	230	99.63	370	160.27
19	8.22	72	31.18	125	54.15	178	77.10	231	100.0	375	162.45
20	8.66	73	31.62	126	54.58	179	77.53	232	100.49	380	164.61
21	9.09	74	32.05	127	55.01	180	77.97	233	100.93	385	166.78
22	9.53	75	32.48	128	55.44	181	78.40	234	101.36	390	168.94
23	9.96	76	32.92	129	55.88	182	78.84	235	101.70	395	171.11
24	10.39	77	33.35	130	56.31	183	79.27	236	102.23	400	173.27
25	10.82	78	33.78	131	56.74	184	79.70	237	102.66	425	184.10
26	11.26	79	34.21	132	57.18	185	80.14	238	103.09	450	195.0
27	11.69	80	34.65	133	57.61	186	80.57	239	103.53	475	205.77
28	12.12	81	35.08	134	58.04	187	81.0	240	103.96	500	216.58
29	12.55	82	35.52	135	58.48	188	81.43	241	104.39	525	227.42
30	12.99	83	35.95	136	58.91	189	81.87	242	104.83	550	238.25
31	13 42	84	36.39	137	59.34	190	82.30	243	105.26	575	249.09
32	13.86	85	36.82	138	59.77	191	82.73	244	105.69	600	259.90
33	14.29	86	37.25	139	60.21	192	83.17	245	106.13	625	270.73
34	14.72	87	37.68	140	60.64	193	83.60	246	106.56	650	281.56
35	15.16	88	38.12	141	61.07	194	84.03	247	106.99	675	292.40
36	15.59	89	38.55	142	61.51	195	84 47	248	107.43	700	303.22
37	16.02	90	39.08	143	61.94	196	84.90	249	107.86	725	314.05
38	16.45	91	39.42	144	62.37	197	85 33	250	108.29	750	324.88
39	16.89	92	39.85	145	62.81	198	85.76	251	108.73	775	335.72
40	17.32	93	40.28	146	63.24	199	86.20	252	109.16	800	346.54
41	17.75	94	40.72	147	63.67	200	86.63	253	109.59	825	357.37
42	18.19	95	41.15	148	64.10	201	87 07	254	110.03	850	368.20
43	18.62	96	41.58	149	64.54	202	87.50	255	110.46	875	379.03
44	19.05	97	42.01	150	64.97	203	87.93	256	110.89	900	389.86
45	19.49	98	42.45	151	65.40	204	88.36	257	111.32	925	400.70
46	19.92	99	42.88	152	65.84	205	88.80	258	111.76	950	411.54
47	20.35	100	43.31	153	66.27	206	89.21	259	112.19	975	422.35
48	20.79	101	43.75	154	66.70	207	89.66	260	112.62	1000	433.18
49	21.22	102	44.18	155	67.14	208	90.10	261	113.06	1500	649.7
50	21.65	103	44.61	156	67.57	209	90.53	262	113.49	2000	866.3
51	22.09	104	45.05	157	68.0	210	90.96	270	116.96	3000	1299.5
52	22.52	105	45.48	158	68.43	211	91.39	275	119.12		
53	22.95	106	45.91	159	68 87	212	91.83	280	121.29		

Based on a density of 62.355 pounds per cu. ft. for water at 62°F.

Theoretical Horsepower

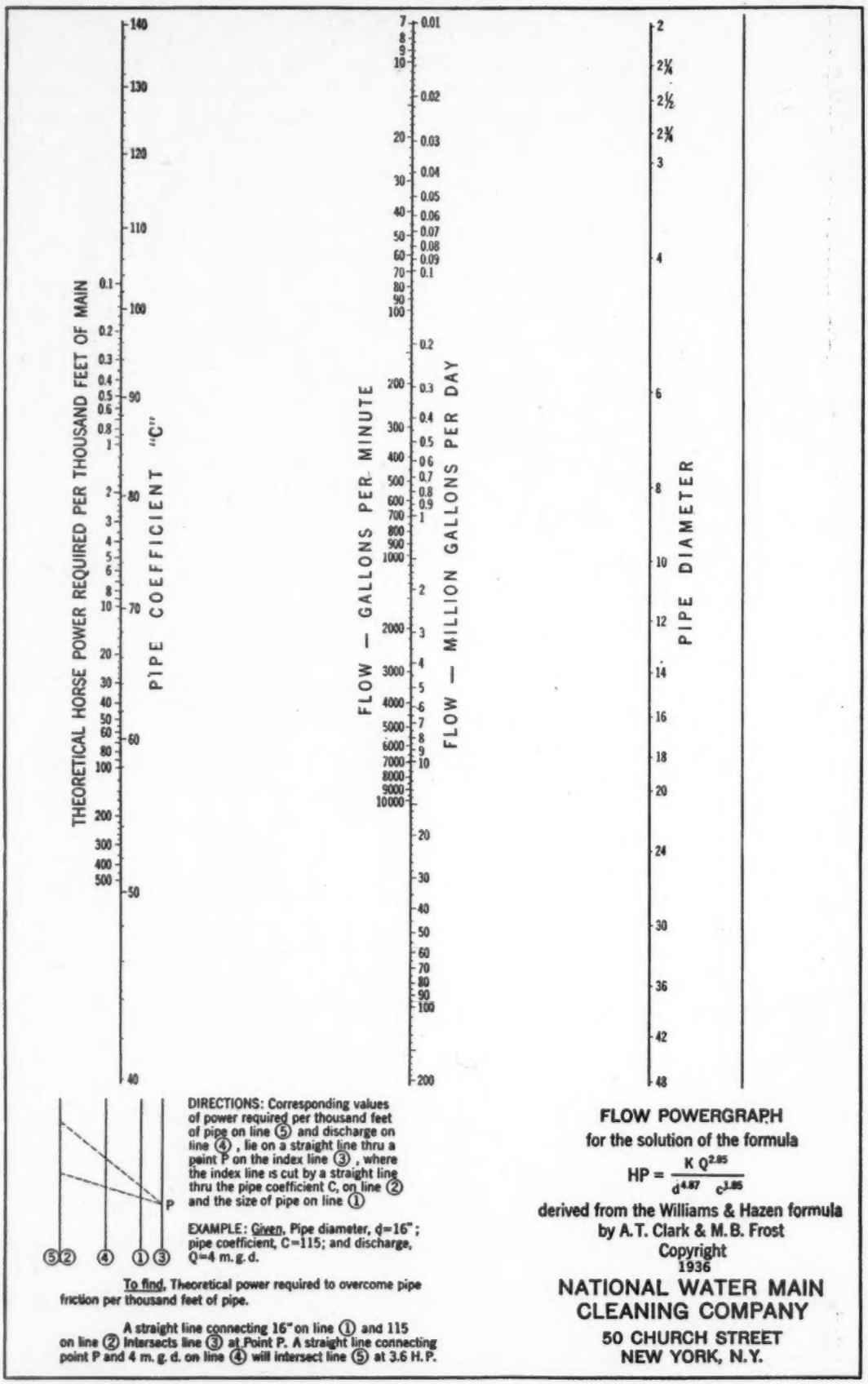
$$\text{Water Horsepower} = \frac{\text{G. P. M.} \times \text{Head in Feet}}{3960}$$

Gallons per minute — Ft.	HEAD IN FEET 10	15	20	25	30	35	40	45	50	60	75	90	100
10	03	04	05	06	08	09	10	.11	.13	.15	.19	.23	.25
15	.04	.06	.08	.09	.11	.13	.15	.17	.19	.23	.28	.34	.38
20	.05	.08	.10	.13	.15	.18	.20	.22	.25	.30	.38	.45	.50
25	.06	.10	.13	.16	.19	.22	.25	.28	.32	.38	47	.57	.68
30	.08	.11	.15	.19	.23	.26	.30	.34	.38	.45	.57	.68	.75
35	.09	.13	.18	.22	26	.31	.35	.40	.44	.53	.66	.80	.88
40	.10	.15	.20	.25	.30	.35	.40	.45	.50	.61	.76	.91	1.01
45	.11	.17	.23	.28	34	.40	.45	.51	.57	.68	.85	1.02	1.14
50	.13	.19	.25	.32	.38	.44	.50	.57	.63	.76	.95	1.14	1.26
60	.15	.23	.30	.38	.46	.53	.61	.68	.76	.91	1.14	1.36	1.52
75	.19	.28	.38	.47	.57	.66	.76	85	.95	1.14	1.42	1.70	1.89
90	.23	.34	.45	.57	.68	.80	.91	1.02	1.14	1.36	1.70	2.04	2.27
100	.25	.38	.50	63	.76	.88	1 01	1.14	1.26	1.51	1.89	2.27	2.52
125	.32	.47	.63	.79	.97	1.10	1.26	1.42	1.58	1.89	1.37	2.84	3.16
150	.38	.57	.76	.95	1.14	1.32	1.52	1.70	1.89	2.27	2.84	3.41	3.79
175	.44	.66	.88	1.10	1.32	1.54	1.78	1.99	2.21	2.65	3.31	3.98	4.42
200	.50	.76	1 01	1.26	1.52	1.77	2.02	2.27	2.52	3 03	3.79	4.54	5.05
250	.63	.95	1.26	1.58	1.90	2.20	2.52	2.84	3.16	3.79	4.73	5.68	6.31
300	.76	1.14	1.51	1.90	2.27	2.65	3.03	3.41	3.79	4.54	5.68	6.82	7.58
350	.88	1.33	1.77	2.21	2.65	3.09	3.54	3.98	4.42	5 30	6.62	7.95	8.84
400	1.01	1 52	2.02	2.52	3.03	3.53	4.04	4.55	5.05	6.06	7.57	9 09	10.10
500	1.26	1.90	2.52	3.16	3 78	4.42	5.05	5.69	6.31	7 58	9.47	11.36	12.63
550	1.39	2.08	2.78	3.47	4.17	4.86	5.56	6.26	6.94	8.33	10.42	12.50	13.89
600	1.52	2.28	3.03	3.79	4.55	5.30	6 06	6.82	7.58	9.09	11.36	13.64	15.15
650	1.64	2.47	3.28	4.10	4.93	5.75	6.56	7 39	8.21	9.85	12.31	14.77	16.41
700	1.77	2.66	3.54	4.42	5.30	6.19	7.07	7.96	8.84	10.60	13.26	15.91	17.68
750	1.89	2.85	3.79	4.74	5.68	6 63	7 58	8.53	9.47	11.36	14.20	17.04	18.94
800	2.02	3.04	4.04	5.05	6.06	7.07	8.08	9.10	10.10	12.12	15.15	18.18	20.20
850	2.15	3.23	4 29	5.37	6.44	7.51	8.58	9.67	10.73	12.87	16.10	19.32	21.46
900	2.27	3.42	4.54	5.68	6.82	7.95	9.09	10.24	11.36	13 63	17.04	20.45	22.73
950	2.40	3.60	4 80	6.00	7.20	8.40	9.60	10.80	11.99	14.39	17.99	21.59	23.99
1000	2.52	3.79	5.05	6 31	7.58	8.84	10.10	11.36	12 63	15 15	18.94	22.73	25.25
2000	5.05	7.57	10.10	12.63	15.15	17.67	20.20	22.72	25.25	30.30	37.87	45.45	50.50
3000	7.57	11.37	15.15	18.94	22.72	26.51	30.30	34.09	37.88	45.45	56.81	68.18	75.75
4000	10.10	15.16	20.20	25 25	30.30	35.35	40 40	45.45	50.50	60.60	75.75	90.90	101.01

NOTE:—to get the BRAKE HORSEPOWER required by the pump use the following formula:—

$$\text{Brake Horsepower} = \frac{\text{G. P. M. x Head in Feet}}{3960 \text{ x Effy. of the pump}}$$

Flow Powergraph


THEORETICAL HORSE POWER REQUIRED PER THOUSAND FEET OF MAIN
PIPE COEFFICIENT "C"
FLOW — GALLONS PER MINUTE
FLOW — MILLION GALLONS PER DAY
PIPE DIAMETER
DIRECTIONS: Corresponding values of power required per thousand feet of pipe on line ⑤ and discharge on line ④, lie on a straight line thru a point P on the index line ③, where the index line is cut by a straight line thru the pipe coefficient C, on line ② and the size of pipe on line ①
EXAMPLE: Given, Pipe diameter, d=16"; pipe coefficient, C=115; and discharge, Q=4 m.g.d.
To find, Theoretical power required to overcome pipe friction per thousand feet of pipe.
A straight line connecting 16" on line ① and 115 on line ② intersects line ③ at Point P. A straight line connecting point P and 4 m.g.d. on line ④ will intersect line ⑤ at 3.6 H.P.
FLOW POWERGRAPH
for the solution of the formula
$HP = \frac{K\,Q^{2.85}}{d^{4.87}\ c^{1.85}}$
derived from the Williams & Hazen formula
by A.T. Clark & M.B. Frost
Copyright
1936
NATIONAL WATER MAIN CLEANING COMPANY
50 CHURCH STREET
NEW YORK, N.Y.

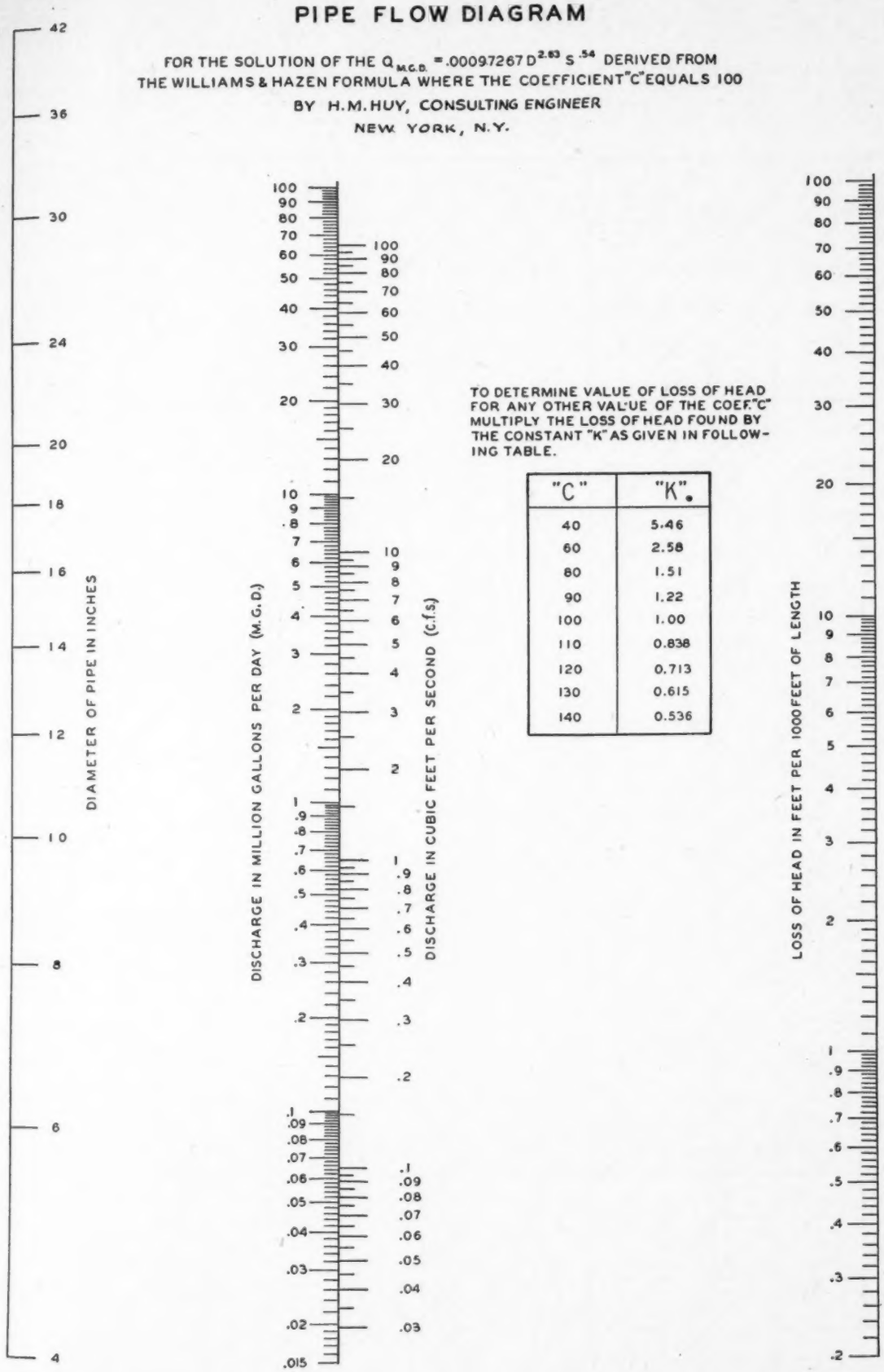
This Highly Useful Graph Was Devised by Arthur T. Clark and M. B. Frost for Simplified Determination of Power Required to Overcome Pipe Friction Under Various Conditions. Also to Determine Condition of Pipe Lines in Service. (Copies of This Graph on Linen Are Being Distributed Gratis by National Water Main Cleaning Co., New York City.)

PIPE FLOW DIAGRAM

FOR THE SOLUTION OF THE $Q_{M.G.D.} = .00097267\,D^{2.63}\,S^{.54}$ DERIVED FROM THE WILLIAMS & HAZEN FORMULA WHERE THE COEFFICIENT "C" EQUALS 100

BY H. M. HUY, CONSULTING ENGINEER

NEW YORK, N.Y.



TO DETERMINE VALUE OF LOSS OF HEAD FOR ANY OTHER VALUE OF THE COEF. "C" MULTIPLY THE LOSS OF HEAD FOUND BY THE CONSTANT "K" AS GIVEN IN FOLLOWING TABLE.

"C"	"K".
40	5.46
60	2.58
80	1.51
90	1.22
100	1.00
110	0.838
120	0.713
130	0.615
140	0.536

(b) FRICTION COEFFICIENT "C": Determine hydrant discharge rate (M.G.D.) at the end of a section of pipe line. Take simultaneous pressure readings at non-flowing hydrants on the same line several hundred feet ahead. Correct all pressure readings for difference in elevations of gages and calculated friction head loss per 1,000 ft. of intervening pipe*. From flow rates observed and known pipe diameter, follow Example (a) to obtain loss of head which would have resulted with coefficient at "C100." This figure divided into the actual (observed) loss of head reveals the "K" factor and from the useful "C-K" table the coefficient "C" can be approximated. *(Accuracy depends upon use of tested pressure gages, careful flow measurements, and inducing a large loss of head between the non-flowing hydrants. For procedure in making hydrant flow tests, see article by Wilson elsewhere in this Section.)

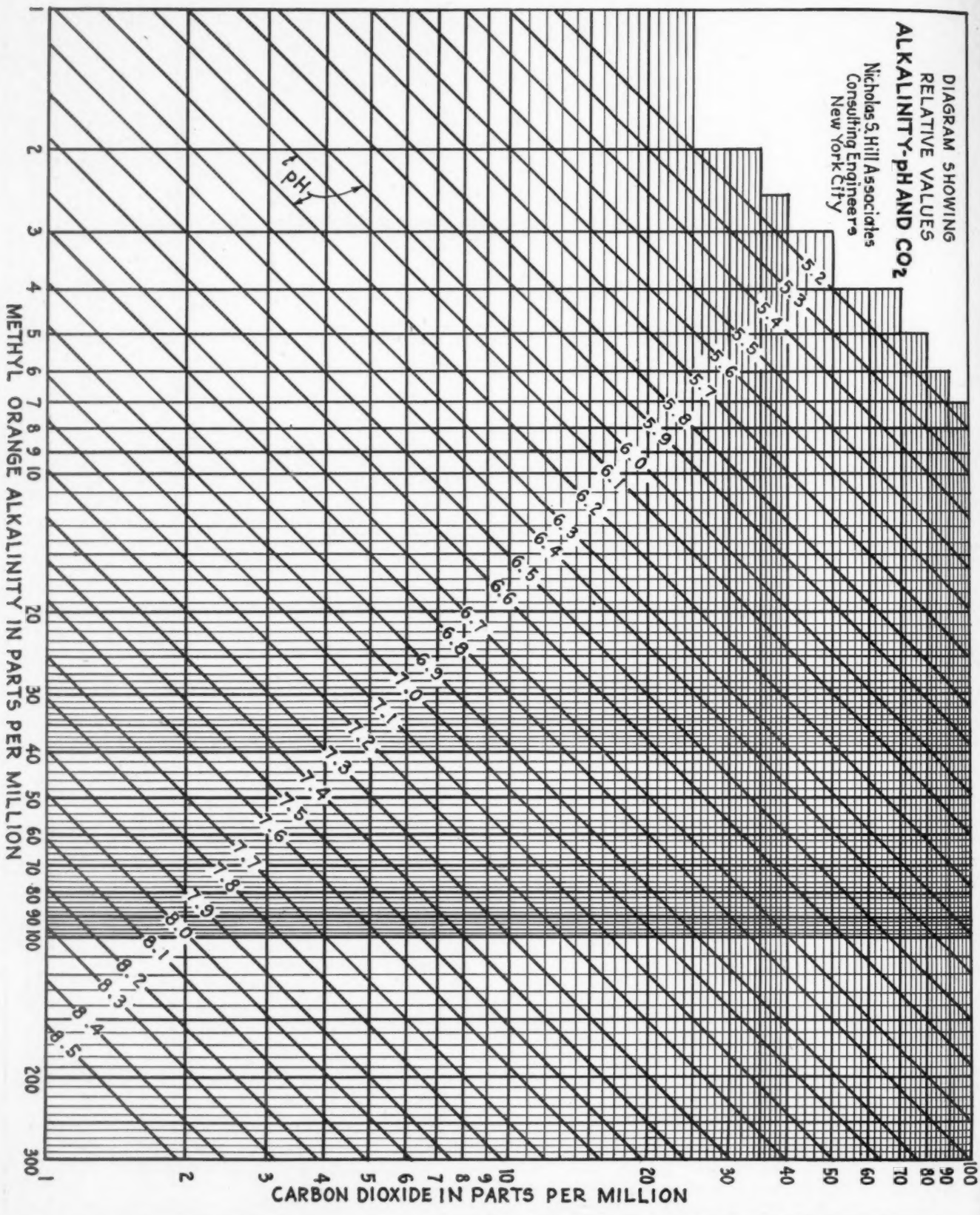
Directions for Application of This Diagram

(a) FRICTION-HEAD LOSS: A line run from pipe diameter (left vertical) through M.G.D. rates of flow (center) intersects friction vertical (right) to reveal computed friction loss per 1,000 ft. of pipe line; or pressure required per 1,000 ft., in pumping, to overcome such loss due to friction at corresponding line capacity. (If the friction coefficient, due to greater roughness or smoothness of the pipe walls, is other than the base used ["C=100"], multiply the head loss obtained by the corresponding "K" factor given for various "C" values in the "C-K" table on the chart.)

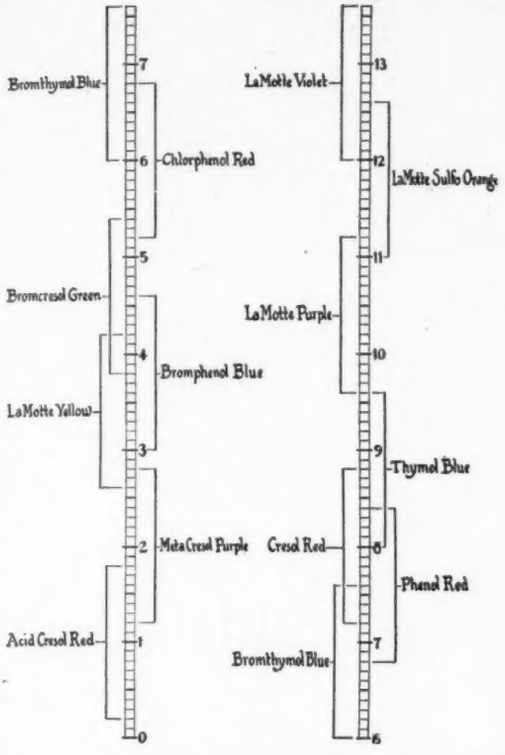
(This diagram is reproduced through courtesy of H. M. Huy and permission of Hydraulic Development Corp. At a location earlier in this Data Section "Practical Methods of Making Flow Tests at Hydrants" are described by P. S. Wilson.

pH CONVERSION CHART

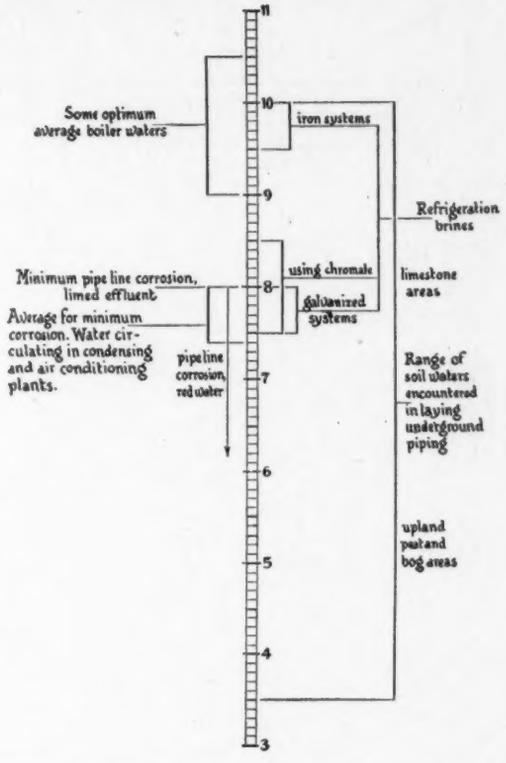
NOTE: *This chart has an especial usefulness in determining free carbon-dioxide content of waters without making the tedious and frequently inaccurate CO_2 titration. Alkalinity and pH readings are more easily and accurately made. To find CO_2 content —Locate pH value diagonal; follow it to intersection with alkalinity value vertical. The horizontal line passing through this same point reveals the correct free CO_2 content. Courtesy Nicholas S. Hill Associates, New York City.*



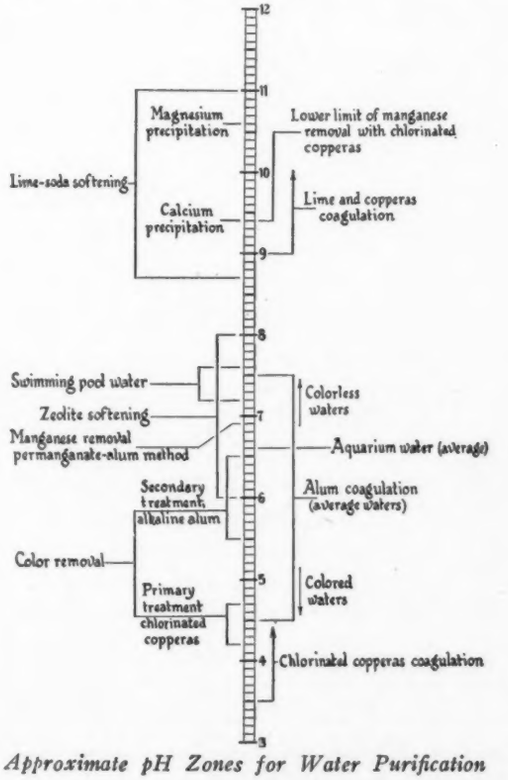
pH ZONES OF IMPORT IN WATER SUPPLY AND SEWAGE TREATMENT PRACTICE *



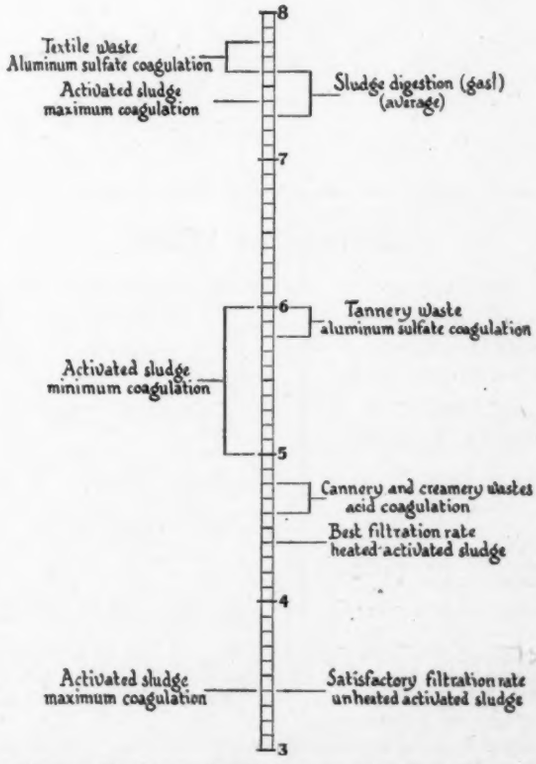
Ranges of Selected Indicators for pH Determination


Some optimum average boiler waters
iron systems
Refrigeration brines
Minimum pipe line corrosion, limed effluent
using chromate
galvanized systems
limestone areas
Average for minimum corrosion. Water circulating in condensing and air conditioning plants.
pipeline corrosion, red water
Range of soil waters encountered in laying underground piping
upland peat and bog areas

Approximate pH Zones Encountered in Common Corrosion Problems



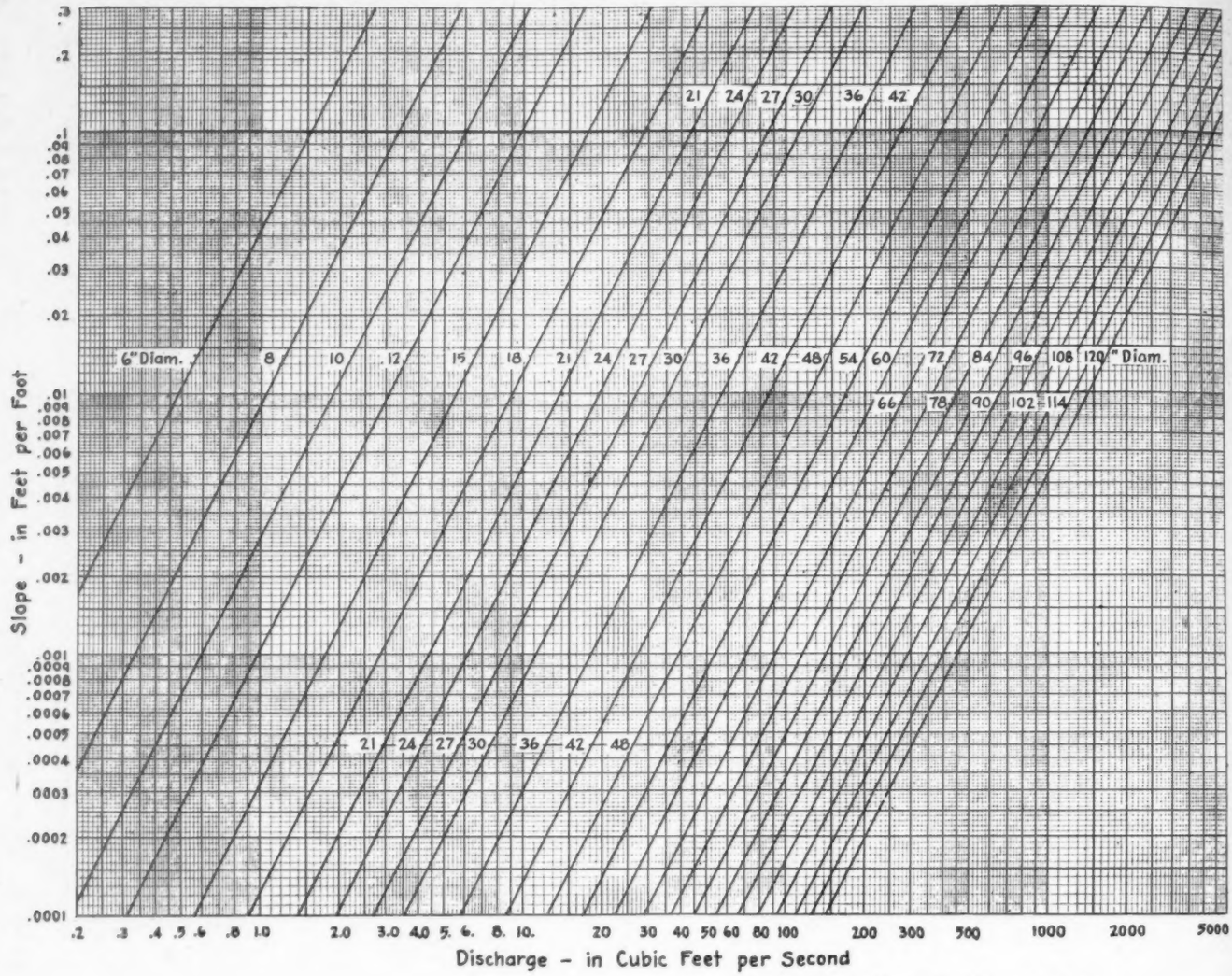
Approximate pH Zones for Water Purification


Textile waste Aluminum sulfate coagulation
Activated sludge maximum coagulation
Sludge digestion (gas!) (average)
Tannery waste aluminum sulfate coagulation
Activated sludge minimum coagulation
Cannery and creamery wastes acid coagulation
Best filtration rate heated activated sludge
Activated sludge maximum coagulation
Satisfactory filtration rate unheated activated sludge

Approximate pH Zones for Treatment of Sewages and Some Industrial Wastes

*Reproduced from the reference work "pH and Its Practical Application"—LaMotte, Kenny & Reed—(Williams and Wilkins, Publishers, Baltimore, Md.)

MEASURING DISCHARGE WITH CIRCULAR ORIFICES



(Courtesy Edward E. Johnson, Inc.)

Blotting Out Waste

Safe Water
delivered night and day
Costs Less
than anything else you buy
· · *but* · ·
Don't Ignore Leaks!

Satisfied customers are worth more to us than revenue secured from water uselessly passing through meters.

INDIANAPOLIS WATER CO.

What Leaks May Cost

Size of Leak	Gallons per 24 Hours	Gallons per Month	Cost per Month
½"	47,600	1,451,800	$156.21
¼"	12,300	375,150	60.05
⅛"	3,200	97,600	19.65
1/16"	860	26,230	6.35
1/32"	215	6,550	1.97

(Above estimates are based on Indianapolis pressures without allowance for friction loss)

The above is a reproduction of the top side of a little blotter sent out to customers, reminding them of the high cost of allowing fixture leaks to persist. If as good at blotting waste as ink, the scheme is praiseworthy.

Incidentally, the Indianapolis Water Company gets in a good public-relations message about satisfied customers being worth more to them than the added revenue from the uselessly metered wastage.

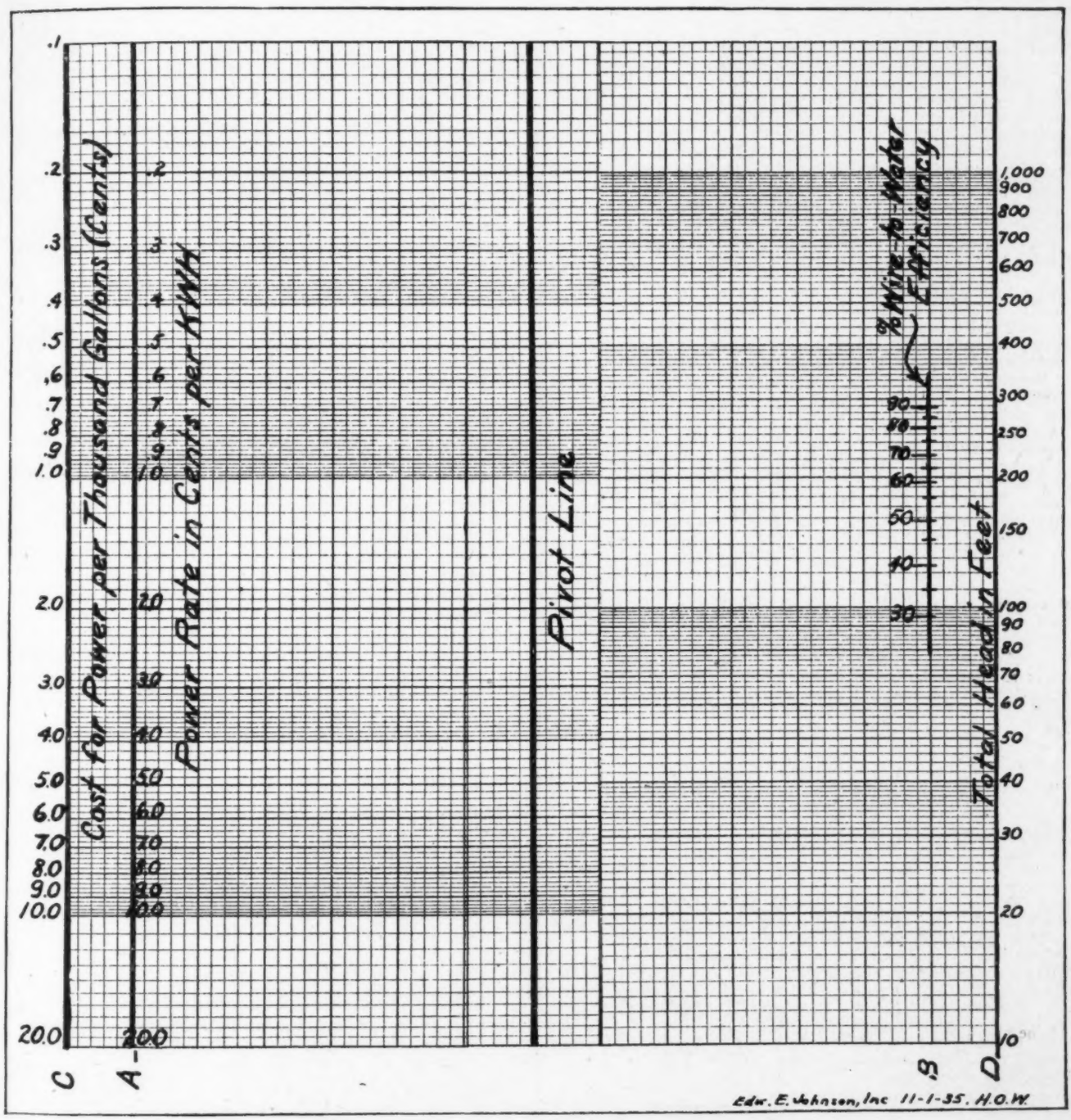
WHAT LEAKS COST

SIZE OF OPENING	AIR		STEAM		WATER	
	Number of Cu. Ft. Wasted per Month 100 Lbs. Pressure	Total Cost of Waste per Month @ 10c per M Cu. Ft.	Number of Lbs. Wasted per Month 100 Lbs. Pressure	Total Cost of Waste per Month @ 80c per M Lbs.	Number of Gallons Wasted per Month 40 Lbs. Pressure	Total Cost of Waste per Month @ 15½c per M Gals.
1"/2	17,798,400	$1,779.84	805,000	$483.00	1,231,000	$192.00
3"/8	9,979,200	997.92	460,000	276.00	692,400	108.00
1"/4	4,449,600	444.96	203,000	121.80	307,700	48.00
1"/8	1,114,560	111.46	50,500	30.30	76,900	12.00
1"/16	278,640	27.86	12,750	7.65	19,200	3.00
1"/32	69,552	6.96	3,175	1.91	4,800	0.80

Courtesy M. B. Skinner Co.

CHART FOR DETERMINATION OF PUMPING COSTS

This chart is used for determining the power cost of pumping water per thousand gallons when the total head, wire-to-water efficiency and power rate are known. In using this chart a ruler is placed from line A (Power Rate in Cents per Kilowatt Hour) to line B (% Wire-to-Water Pump Efficiency). A pin or pencil point is placed against the edge of the ruler on the Pivot Line and the ruler is then pivoted to the proper point on line D (Total Head in Feet). The Cost for Power per Thousand Gallons can then be read directly from line C at the left of the chart. *(Courtesy Edward E. Johnson, Inc.)*



ROOTS AND POWERS OF NUMBERS*

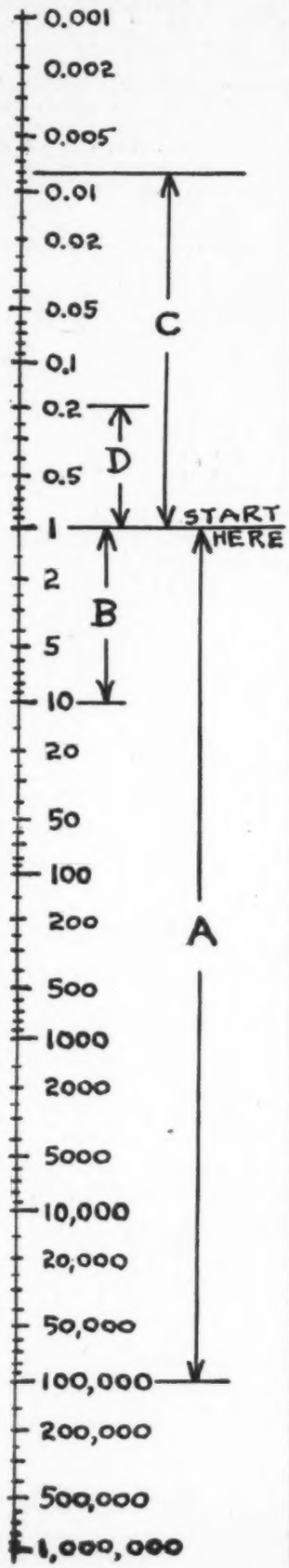
A Chart Which Saves Many Tables

Take any slide rule and lay it end to end nine times, and each time lay off the principal dividing lines, you will have a chart exactly like this one except that it will be much longer and therefore it will be much more accurate. That is what I did in preparing this chart. Then I reduced it to this much smaller size. To keep track of the digits you simply read the numbers exactly as they stand on the chart. No juggling of figures is necessary. I do not know of any other other method that is as simple as this. All other methods require "juggling of digits," as they say.

For example, what is the 5th root of 100,000? Measure the distance A from 1 to 100,000 as indicated on the chart. The distance B must then be exactly 1/5th of the distance A and there is your answer, namely, 10. In other words, divide the distance A by the root and the quotient shows you the distance to measure from 1 to find the answer. Always measure from "1" in either direction. "One" is always the starting point. To extract the square, cube, or other root of fractions is usually more complex than extracting roots of whole numbers. However, with this chart one is just as easy as the other.

For example, what is the cube root of .008? Measure the distance C from .008 to the starting point "1" and divide it by 3 and you get the distance D which tells us that the answer is 0.2.

A method that is as easy as any to find a third, fourth, fifth, etc., of any distance, is to use a pair of dividers. Adjust the dividers until you get the distance D exactly ⅓ of the distance C and the chart gives the answer without any mathematical calculations whatever. With this chart you can determine the 3.127 power for instance—any power in fact. And you can extract the 4.37 root or any other root, all without mathematical jugglery.



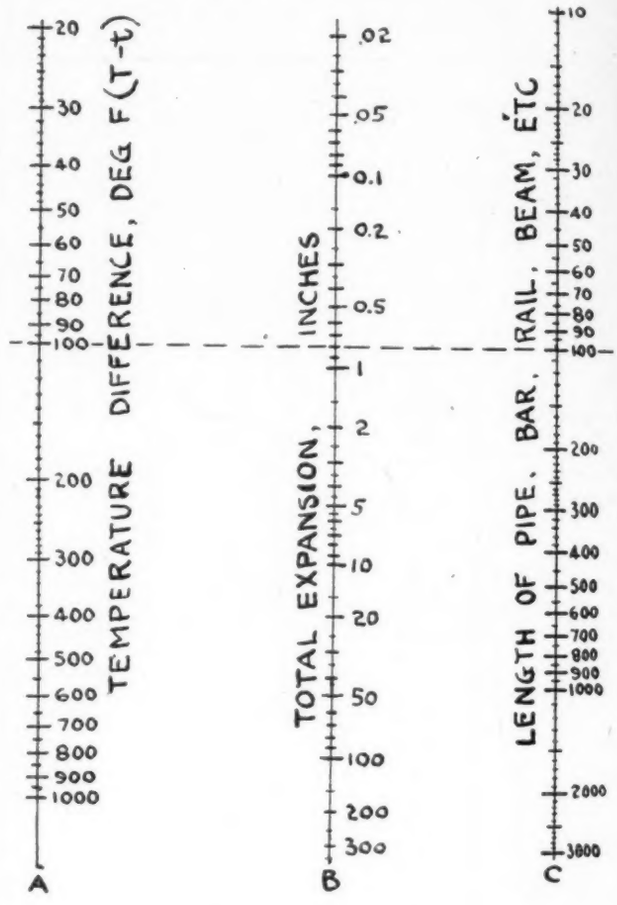
*From an article by W. E. Schaphorst, M. E., Newark, N. J., in WATER WORKS & SEWERAGE, January, 1939.

EXPANSION CHART*

This chart is useful for determining the expansion in piping, rods, tubes, beams, shafts, columns, struts, etc., for any ordinary temperature difference. It makes "longhand figuring" unnecessary. Simply lay a straight-edge across the chart once or stretch a fine black thread across, as indicated by the dotted line, and the problem is solved.

Example: If a certain pipe line 100 ft. long is subjected to a temperature variation of 100 deg. F., what will be the total expansion in inches?

Simply connect the 100 deg. *temperature difference*, column A,



with the 100 ft. length, column C. The intersection with column B gives the answer as 0.8 in. That is all there is to it.

The chart can also be used for determining the allowable temperature difference where a definite amount of space is available for expansion and contraction. Thus if the length of the pipe is 100 ft. and the allowable expansion is 0.8 in. the same line would show that a temperature difference of 100 deg. F. would be the limiting amount.

*From an article by W. F. Schaphorst, M.E., Newark, N. J., in WATER WORKS & SEWERAGE, March, 1939.

CHART FOR CONVERTING GRAINS PER GALLON TO POUNDS PER MILLION AND THE REVERSE

Courtesy W. Donaldson and Fuller & McClintock, Engineers

POUNDS OF CHEMICAL REQUIRED PER HOUR FOR VARIOUS PUMPAGES & DOSES

PUMPAGE		DOSE - POUNDS PER MILLION GALLONS															
MILLION GALLONS 24 HRS.	THOUSAND GALLONS PER HOUR	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
		DOSE - GRAINS PER GALLON															
		.07	.14	.21	.28	.35	.42	.49	.56	.63	.70	.77	.84	.91	.98	1.05	1.12
1.0	41.7	.417	.833	1.25	1.67	2.08	2.50	2.92	3.33	3.75	4.17	4.58	5.00	5.42	5.83	6.25	6.67
1.5	62.5*	.625	1.25	1.88	2.50	3.13	3.75	4.38	5.00	5.63	6.25	6.88	7.50	8.13	8.75	9.38	10.0
2.0	83.3	.833	1.67	2.50	3.33	4.17	5.00	5.83	6.67	7.50	8.33	9.17	10.0	10.8	11.7	12.5	13.3
2.5	104	1.04	2.08	3.13	4.17	5.21	6.25	7.29	8.33	9.38	10.4	11.5	12.5	13.5	14.6	15.6	16.7
3.0	125*	1.25	2.50	3.75	5.00	6.25	7.50	8.75	10.0	11.3	12.5	13.8	15.0	16.3	17.5	18.8	20.0
3.5	146	1.46	2.92	4.38	5.83	7.29	8.75	10.2	11.7	13.1	14.6	16.0	17.5	19.0	20.4	21.9	23.3
4.0	167	1.67	3.33	5.00	6.67	8.33	10.0	11.7	13.3	15.0	16.7	18.3	20.0	21.7	23.3	25.0	26.7
4.5	187	1.88	3.75	5.63	7.50	9.38	11.3	13.1	15.0	16.9	18.8	20.6	22.5	24.4	26.3	28.1	30.0
5.0	208	2.08	4.17	6.25	8.33	10.4	12.5	14.6	16.7	18.8	20.8	22.9	25.0	27.1	29.2	31.3	33.3
5.5	229	2.29	4.58	6.88	9.17	11.5	13.8	16.0	18.3	20.6	22.9	25.2	27.5	29.8	32.1	34.4	36.7
6.0	250*	2.50	5.00	7.50	10.0	12.5	15.0	17.5	20.0	22.5	25.0	27.5	30.0	32.5	35.0	37.5	40.0
6.5	271	2.71	5.42	8.13	10.8	13.5	16.3	19.0	21.7	24.4	27.1	29.8	32.5	35.2	37.9	40.6	43.3
7.0	292	2.92	5.83	8.75	11.7	14.6	17.5	20.4	23.3	26.3	29.2	32.1	35.0	37.9	40.8	43.8	46.7
7.5	312	3.13	6.25	9.38	12.5	15.6	18.8	21.9	25.0	28.1	31.3	34.4	37.5	40.6	43.8	46.9	50.0
8.0	333	3.33	6.66	10.0	13.3	16.7	20.0	23.3	26.7	30.0	33.3	36.7	40.0	43.3	46.7	50.0	53.3
8.5	354	3.54	7.08	10.6	14.2	17.7	21.3	24.8	28.3	31.9	35.4	39.0	42.5	46.0	49.6	53.1	56.7
9.0	375*	3.75	7.50	11.3	15.0	18.8	22.5	26.3	30.0	33.8	37.5	41.3	45.0	48.8	52.5	56.3	60.0
9.5	396	3.96	7.92	11.9	15.8	19.8	23.8	27.7	31.7	35.6	39.6	43.5	47.5	51.5	55.4	59.4	63.3
10.0	417	4.17	8.33	12.5	16.7	20.8	25.0	29.2	33.3	37.5	41.7	45.8	50.0	54.2	58.3	62.5	66.7
10.5	437	4.38	8.75	13.1	17.5	21.9	26.3	30.6	35.0	39.4	43.8	48.1	52.5	56.9	61.3	65.6	70.0
11.0	458	4.58	9.17	13.8	18.3	22.9	27.5	32.1	36.7	41.3	45.8	50.4	55.0	59.6	64.2	68.8	73.3
11.5	479	4.79	9.58	14.4	19.2	24.0	28.8	33.5	38.3	43.1	47.9	52.7	57.5	62.3	67.1	71.9	76.7
12.0	500*	5.00	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0
12.5	521	5.21	10.4	15.6	20.8	26.0	31.3	36.5	41.7	46.9	52.1	57.3	62.5	67.7	72.9	78.1	83.3
13.0	542	5.42	10.8	16.3	21.7	27.1	32.5	37.9	43.3	48.8	54.2	59.6	65.0	70.4	75.8	81.3	86.7
13.5	562	5.63	11.3	16.9	22.5	28.1	33.8	39.4	45.0	50.6	56.3	61.9	67.5	73.1	78.8	84.4	90.0
14.0	583	5.83	11.7	17.5	23.3	29.2	35.0	40.8	46.7	52.5	58.3	64.2	70.0	75.8	81.7	87.5	93.3
14.5	604	6.04	12.1	18.1	24.2	30.2	36.3	42.3	48.3	54.4	60.4	66.5	72.5	78.5	84.6	90.6	96.7
15.0	625*	6.25	12.5	18.8	25.0	31.3	37.5	43.8	50.0	56.3	62.5	68.8	75.0	81.3	87.5	93.8	100.0

* Exact Values

‡ COURTESY FULLER & MCCLINTOCK ENGINEERS

1 grain per gallon = 143 pounds per million gallons = 5.95 lbs. per hour for each million gallons
0.70 " " " = 100 " " " " " = 4.17 " " " " " " "

Example: What weight of Chemical must be fed each hour to give a 70 lb dose for a pumpage of 8.0 M.G.D. Opposite 8.0 M.G.D and under 70 find 23.3, which is the correct weight.

Note: It is now becoming modern practice to record and report all chemical dosages in pounds per million (P.M.G.) and thereby have simplification in reporting and recording, rather than using the older scheme involving grains per gallon, parts per million, etc.

TABULATION OF YIELDS FROM CIRCULAR ORIFICE WEIRS

(Range from 56 G. P. M. to 2,000 G. P. M.)

YIELD IN GALLONS PER MINUTE

Head of Water in Tube Above Center of Orifice	4-inch Pipe 2½-inch Opening	4-inch Pipe 3-inch Opening	6-inch Pipe 3-inch Opening	6-inch Pipe 4-inch Opening	6-inch Pipe 5-inch Opening	8-inch Pipe 4-inch Opening	8-inch Pipe 5-inch Opening	8-inch Pipe 6-inch Opening	10-inch Pipe 6-inch Opening	10-inch Pipe 7-inch Opening	10-inch Pipe 8-inch Opening
5 inches	56 gpm	93 gpm	.....	.....	.....	.....	.....	.....	.....	.....	.....
6 "	62 "	102 "	82 gpm	155 gpm	300 gpm	148 gpm	240 gpm	380 gpm	.....	.....	.....
7 "	66 "	110 "	88 "	168 "	325 "	160 "	260 "	410 "	370 gpm	550 gpm	850 gpm
8 "	70 "	118 "	94 "	180 "	350 "	170 "	280 "	440 "	395 "	590 "	900 "
9 "	75 "	126 "	100 "	190 "	370 "	180 "	295 "	465 "	420 "	630 "	950 "
10 "	80 "	132 "	106 "	200 "	390 "	190 "	310 "	490 "	440 "	660 "	1000 "
12 "	87 "	145 "	115 "	220 "	425 "	210 "	340 "	540 "	480 "	720 "	1100 "
14 "	94 "	156 "	125 "	238 "	460 "	225 "	370 "	580 "	520 "	780 "	1190 "
16 "	100 "	168 "	132 "	253 "	490 "	240 "	390 "	620 "	560 "	840 "	1275 "
18 "	106 "	178 "	140 "	268 "	520 "	255 "	415 "	660 "	595 "	890 "	1350 "
20 "	112 "	188 "	150 "	283 "	550 "	270 "	440 "	695 "	625 "	940 "	1420 "
22 "	118 "	198 "	158 "	298 "	575 "	280 "	460 "	725 "	660 "	980 "	1480 "
25 "	125 "	210 "	168 "	318 "	610 "	300 "	490 "	780 "	700 "	1050 "	1580 "
30 "	138 "	230 "	182 "	350 "	670 "	330 "	540 "	850 "	760 "	1150 "	1725 "
35 "	150 "	250 "	198 "	375 "	725 "	360 "	580 "	920 "	820 "	1240 "	1865 "
40 "	160 "	265 "	210 "	400 "	780 "	380 "	620 "	980 "	880 "	1330 "	2000 "
45 "	170 "	280 "	223 "	425 "	820 "	400 "	660 "	1040 "	940 "	1410 "	.....
50 "	180 "	300 "	235 "	450 "	870 "	425 "	700 "	1100 "	990 "	1480 "	.....
60 "	195 "	325 "	260 "	490 "	950 "	465 "	760 "	1200 "	1090 "	1610 "	.....

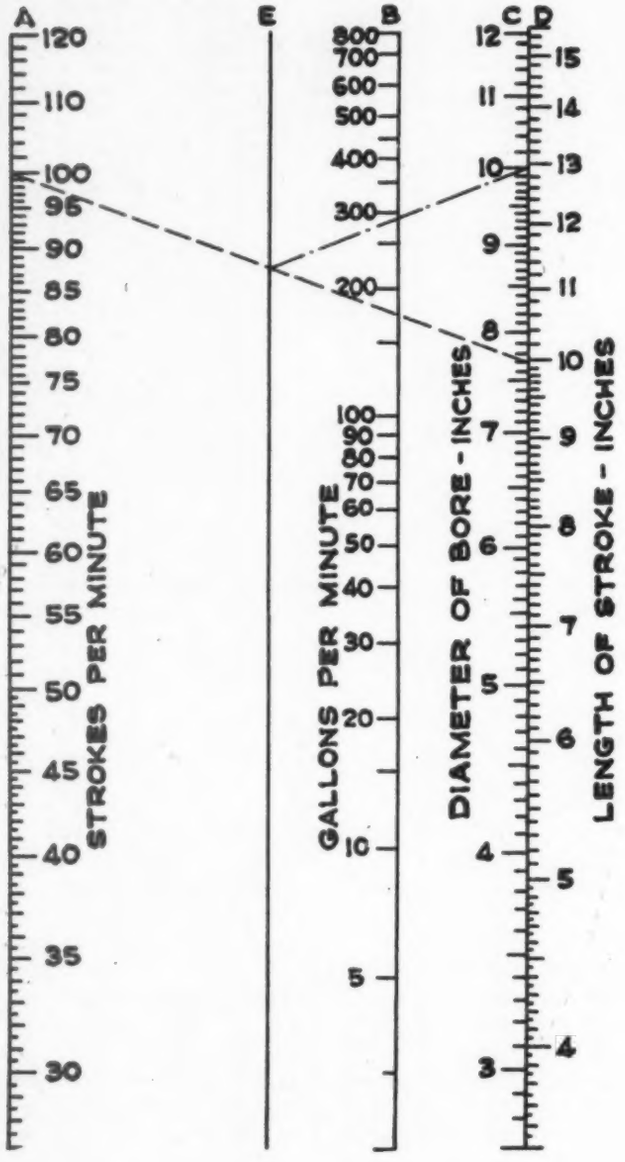
CAPACITY OF RECIPROCATING PUMPS

This nomograph shows the capacity of a reciprocating pump operating without slip where the size and number of strokes is known.

Example:

A pump of 10-in. bore, 10-in. stroke running 100 strokes per minute: Locating 100 on line "A" and 10-in. on line "D" we draw a line between them; then locating the intersection of this line with line "E" and locating 10-in. on line "C" we draw a connecting line. Where this line crosses "B" we have the delivery, or 290 G.P.M., of the reciprocating pump.

(From "Data Handbook" of Economy Pumps, Inc.)



DISTINGUISHING BETWEEN CHLORAMINE AND "FREE" CHLORINE

To distinguish between "free," or hypochlorite, chlorine and chlorine in the chloramine form, a test involving the decolorizing power of the residual chlorine seems to serve as a practical method. In slightly acid solution "free" or hypochlorite chlorine will bleach dilute methyl-orange indicator added to 100 cc. samples, when present to the extent of as little as 0.02 p.p.m.

The following distinguishing test has been suggested by R. D. Scott, Chief Chemist, Ohio State Department of Health:

Dissolve 0.5 gram methyl orange in one liter of water. Dilute 5.9 cc. of this solution to 100 cc. If added to 100 cc. of water containing 0.1 p.p.m. free chlorine 1 cc. of this dilute methyl orange solution will be decolored upon acidifying the sample slightly.

Accordingly, after determining the alkalinity of the water to methyl-orange, using the standard indicator, add to another 100 cc. portion 2 cc. of N-10 acid in excess of that required to just neutralize the alkalinity. Add 0.2 cc. of the dilute methyl-orange indicator. If the pink color disappears, repeat the addition until the pink cast persists for at least 5 minutes. Each 1 cc. of indicator decolorized indicates 0.1 p.p.m. "free" chlorine.

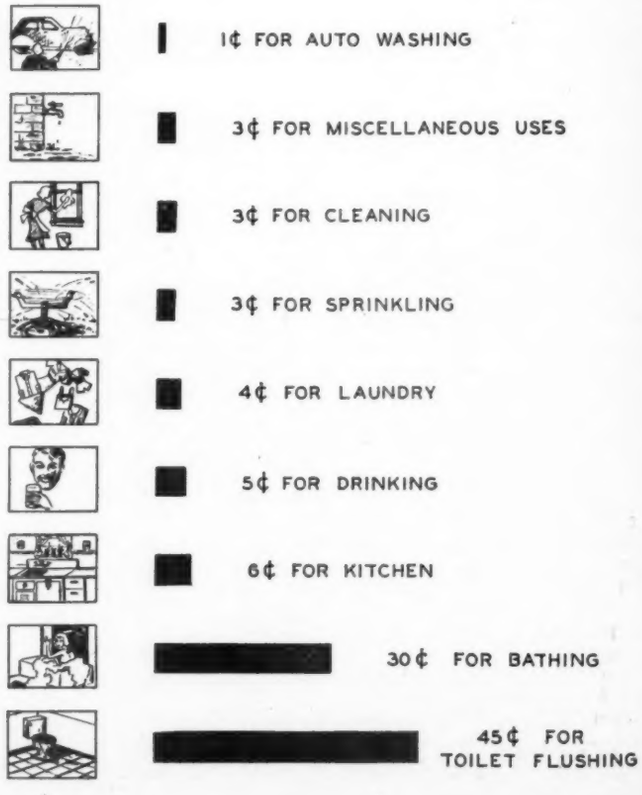
From the total available (residual) chlorine, as measured by the orthotolidin method, deduct the "free" chlorine value and the residue can be, for all practical intent, assumed to be that residual in the form of chloramines.

(NOTE: In this test the possible presence of manganese (or nitrites, above 0.5 p.p.m. N.) must be considered and taken into account in correcting the total residual chlorine.)

WHERE THE WATER DOLLAR GOES

Here is an interesting and enlightening chart taken from the 22nd Annual Report of the Water Department, Springfield, Ill. It is based on a survey made by H. V. Pedersen, Water Supt., at Marshalltown, Iowa, to determine what percentage of water in the average consumer's home goes for various uses.

The Springfield folks have taken these percentages and made them more real to the customer, by showing him that out of every dollar paid for water used it only cost him 1 cent to wash his car, only 4 cents for laundry work at home, 3 cents for sprinkling in summer.



INFORMATION ON WATER AND SEWAGE WORKS PROBLEMS* —WHERE TO FIND IT

By L. H. ENSLOW
Editor WATER WORKS AND SEWERAGE

The subject which has been assigned me is of a rather large order and will be dealt with only in part. I will content myself with stating where information of various sorts may be found.

It goes without saying that information required by water works men and sewage works operators is not concentrated in two or three books. The nearest approach to concentrated information for water works men is found in the manual published by the American Water Works Association—"Water Works Practice."

Regardless of the availability of published information, reference books, etc., it is well known that practical experience is essential in solving most water and sewage problems.

Reference Works. Text books, manuals, hand-books, journals, and catalogs are named in the attached list of recommended reference work for water sewage works men.

The list represents the majority opinions of operating men, managers, engineers and chemists. I was somewhat reticent about taking the sole responsibility of naming such a list and therefore called on men fully qualified to offer suggestions to make up a set of reference works.

I had not thought of catalogs put out by manufacturers as being of value beyond use in specifying and purchasing materials and equipment, but one of my collaborators who is Superintendent of Operations of a company operating a large number of plants states the following:

"I find that in my own work the most frequently consulted books are the catalogs of the manufacturers of water works materials and equipment. These catalogs are of constant use, not only in connection with the purchasing of the goods listed, but also due to the vast amount of information contained in them as to the available styles, weights, dimension, capacities, and many other features."

Small Works and Large Works. It had been my thought that I might make up a list of reference works which would cover the needs of managers and operators of small and medium sized works and another which would be more extensive for the larger works. A superintendent of a small works writes as follows, and I am forced to agree with him to a major degree.

"In my opinion, the small town superintendent should have just as complete knowledge of fundamentals as the large town superintendent and in fact would have problems coming to his personal attention which might require more detailed knowledge than would be the case with the superintendent of a large system who would delegate such work to various assistants."

Current Information. Current information is best obtained through the technical journals, trade papers, manufacturers' publications.

Attending meetings, listening to papers read and discussion of these, is of paramount value. Demonstrations such as those put on during meetings are extremely valuable and operations of this nature can not, as a rule, be found described in books. Operating papers in the journals and trade publications, however, frequently describe "operating kinks" of a great value.

Reprints and Bulletins. Manufacturers and Trade Associations frequently distribute information of value in the nature of reprinted articles, house-organs or bulletins. Ofttimes these are mailed out only upon request, or by sending in a coupon incorporated in an advertisement. It therefore pays to read the ads.

Such publications usually contain valuable information and often serve a very useful purpose. If they are not bulky these may be filed away or placed in a loose leaf binder under the heading of the subject matter, as for example, "Meters and Meter Maintenance," "Tanks and Standpipes," "Water Treatment," "Algae Control," etc., etc. If bulky, they may be torn apart and the most valuable parts filed for future reference. It is surprising how much worthwhile information and data can thus be accumulated in a readily available form and at practically no cost. Some men make a practice of tearing apart technical magazines and filing the desired contents under subject matter heading where the information will be more readily available thereafter.

Filing Schemes. I have found the following filing schemes practical, serviceable and inexpensive:

For the office, the old fashioned and inexpensive box letter-file, made of cardboard and wood, is very useful. The index is removed and the clippings, reprints, etc., covering a single "subject-head" are placed in envelopes or folders properly labeled and preserved in the box files. These boxes are properly labeled to show their subject matter contents and stored on end on a shelf as one would store a set of books. As the contents of a single box grows it may be necessary later to devote an entire box to a single subject head. "Water Treatment" for example will probably require a single box which may contain a folder on water softening, and others on coagulation, aeration, corrosion control, etc. One subject head can be broken down into as many sub-divisions as may appear desirable. I have one which contains 16 sub-divisions and this assists in prompt location of the desired information when needed.

Some people may prefer to use metal box files of the same size which are also available, but more expensive. Others may prefer a set of loose leaf binders, but I find the boxes are simpler, offer more protection to the filed sheets and keep the dust out.

Information such as conversion factors, data tables and formulae which are more frequently used may best be filed in a pocket-size loose leaf book. The paper can be reinforced with little gummed linen eyelets where the rings pass through and the sheet folded if need be to fit into the binder or it may be cut into parts and glued at its corners to both sides of a filler sheet of the binder. An index in the binder serves a useful purpose in that it facilitates location of the desired tables of data or conversion figures. For work in the field the pocket size loose-leaf book is almost indispensable. I have one fairly well filled with curves and data cut from magazines, journals, and booklets distributed by manufacturers.

Short Courses for Superintendents and Operators. This scheme has been followed successfully in many states. The courses are so arranged that those taking it are not in the least embarrassed by any lack of prior education. Much of the course is of a practical nature and the chemistry and biology lectures and laboratory work are made simple and attractive. Superintendents who have attended these schools have found them very helpful and have returned to take the courses another year, which is an excellent indication of their usefulness. Materials men, factory representatives, sales engineers and other specialists are called upon to give demonstrations of important equipment used in water works systems. All of this is very useful and helpful to the manufacturer as well as the "students." Questions are freely asked and answered.

I do not hesitate to recommend the Short Course to every one of you and I believe that you will find the slight expense and the time spent a thoroughly good investment.

Special and Unusual Problems. When a special or an unusual problem presents itself to water works or sewage works operators, information required may not be easily found in published form. In such instances the State Health Department personnel can be of material help and I can assure you, as a former operator and later affiliated with two State Departments of Health, that the engineers and chemists connected with the Department are always glad to assist the operator or the management of a public works wherever they can. Call freely on your Health Department Engineer for information and advice and you will be the gainer.

In instances, the problem will be of a nature that can be solved by utilizing information obtainable through the Research

*A paper presented before the Southeastern Section, American Water Works Association in 1932. Revised in 1939.

and Development Departments of manufacturers, Institutes, or Trade Associations. In my capacity of Research Engineer of the Chlorine Institute I have frequently been able to supply special information covering problems in chlorine application which, of nature, I was better prepared to give than someone else because of my long and intimate contact with chlorinating problems. Other associations are equipped to give similar service in connection with their products.

I have not understood why consulting engineers and chemists are not more regularly approached for advice and information covering special problems. I believe that managers of water and sewage systems overlook the value of having their municipality retain consultants on an annual fee basis in order to be in a position to seek advice as frequently as need be by mail or 'phone. This is practiced by some cities but as a rule the small municipalities, which would profit relatively more perhaps than the larger cities by such an arrangement, fail to take advantage of this relatively low cost service. Consultants are not prone to charge small municipalities as heavy as they would those more able to pay. Industry finds that it pays to retain consultants on an annual fee basis and it sems that municipalities should find the same.

I believe that every home should have its family physician and that every municipality needs the services of a consulting engineer to prescribe "remedies" over the 'phone just as the family physician does and thus frequently saves the patient much discomfort or prevents the necessity of a "major operation" later.

I find an increasing tendency on the part of small towns to retain chemists and engineers to supervise plant operations and at the same time supply advice and information whenever required. If engineers and chemists were as good salesmen as are lawyers and physicians, more of this kind of valuable service would be made use of.

Visiting. An excellent means of procuring information covering operation and maintenance is by visiting water and sewage works plants. Many of us are prone to inspect the works of our neighbors with a critical eye. We see too easily the weak points. If, on the other hand, we should look around and make inquiries in a less critical frame of mind, or with an attitude of seeking all possible information, more of value could be learned.

When one attends a water or sewage works meeting or a short course he is actually "visiting" because there he meets and tasks with men from other places. That is next in value to an actual visit or first hand inspection of the other fellow's works. I wish to stress the importance of visiting and exchanging experiences.

Acknowledgment. I acknowledge, with appreciation, the assistance of the several men who contributed suggestions of reference books, catalogs, etc., which proved helpful in preparing the following lists:

LIST NO. 1 —FOR WATER WORKS MANAGERS AND OPERATORS

[For Small and Moderate Size Systems.]

Books	*Publishers*	*Authors*
Water Works Practice—Manual of the A. W. W. A. ($5.00)	Williams & Wilkins, Baltimore	Various
Manual of Water Works Accounting	Am. Water Works Assn., New York City	Various
Manual of Water Purification Practice (in preparation)	Am. Water Works Assn., New York City	Various
The Operation of Water Filtration Plants (F)	N. C. State Dept. Health, Raleigh, N. C.	
Water Supply Control (nominal charge)	N. Y. State Dept. Health, Albany, N. Y.	
Water Works Handbook ($7.00)	McGraw-Hill Co., New York City	Flynn, Weston & Bogert
Water Purification Control, 2nd Edition ($1.75)	Williams & Wilkins, Baltimore, Md.	Hopkins
Standard Methods of Water Analysis, 8th Ed. ($2.50)	A. P. H. A., New York City	A. W. W. A. & A. P. H. A.
Lab. Manual—Chemical & Bacterial Analysis Water and Sewage, 2nd Edition ($2.50)	McGraw Hill Co., New York City	Theroux, Eldridge, Mallman
Water Purification ($7.00)	McGraw Hill Co., New York City	Ellms
Copper Sulphate in Control of Micro Organisms (F)	Nichols Copper Co., New York City	Hale
Pump Data (F)	Economy Pumping Mach. Co., Chicago	
Conversion Factors for Engineers (F)	The Dorr Co., New York City	
Engineering Data in Flow of Fluids in Pipes (F)	Crane Co., Chicago	
Bul. No. 21 (a Handbook on Hydraulics) (F)	National Tube Co., Pittsburgh, Pa.	
Handbook of Cast Iron Pipe (F)	Cast Iron Pipe Research Assn., Chicago	
Chlorination of Water	John Wiley & Sons, New York City****	Race
Technical Bulletins on Chlorination (F)	Wallace & Tiernan Co., Newark, N. J.	Various
Hydraulic Tables—3rd Ed. ($2.00)	John Wiley & Sons, New York City	Williams & Hazen
Cameron Hydraulic Data (F)	Ingersoll-Rand, Phillipsburgh, N. J.	
Handbook on Fire Protection ($4.50)	D. Van Nostrand Co., New York City	Crosby, Fiske & Forster
Fire Engine Tests and Fire Stream Tables (F)	National Board of Fire Underwriters, N. Y. C.	
Plumber's Handbook ($4.00)	McGraw-Hill Co., New York City	Dibble
Examination of Water—6th Ed. ($3.00)	John Wiley & Sons, New York City	Mason & Buswell
Public Water Supplies—3rd Ed. ($6.00)	John Wiley & Sons, New York City	Turneau & Russell
American Civil Engineering Handbook—5th Ed. ($8.00)	John Wiley & Sons, New York City	Merriman & Wiggin
Lefax—Data Sheets for Loose Leaf Note Books	Lefax, Inc., Philadelphia, Pa.	Various
Water Supply & Treatment (F)	National Lime Assn., Washington, D. C.	Hoover
A. B. C. of Hydrogen Ion Control (F)	LaMotte Company, Baltimore, Md.	
Modern P. H. Control (F)	W. A. Taylor Co., Baltimore, Md.	
"Hydro-tite" Booklet of Useful Information (F)	Hydraulic Development Corp., New York, N. Y.	
Microscopy of Drinking Water (4th Ed. $7.00)	John Wiley & Sons, New York City	Whipple-Fair
Plane Surveying ($3.50)	John Wiley & Sons, New York City	Tracey
Water Treatment and Purification ($2.50)	McGraw Hill Co., New York City	Ryan
Water Supply & Sewerage ($5.00)	McGraw-Hill Co., New York City	Steel
"The Hardy-Cross Method"—Bul. 286	Univ. of Illinois, Eng. Explt. Sta.	Hardy

(F) Available as Free Publication at this writing, Apr., 1938.
*Revised and enlarged, Apr., 1939.
****Out of print. Try National Bibliophile Service, 347 Fifth Ave., N. Y. City.

Journals and Magazines (*Applies to Lists* 1 *and* 2)

Journal and Monographs of the American Waterworks Association
Journal of the New England Water Works Association.
Current Water Works Technical Magazines and Trade Papers.

LIST NO. 2—FOR MANAGERS, CHEMISTS AND OPERATORS OF LARGE WATER WORKS

(In addition to List No. 1 for smaller works)

Books	*Publishers*	*Authors*
Fresh Water Biology ($7.00)	John Wiley & Sons, New York City	Ward & Whipple
Fresh Water Algae ($6.00)	McGraw-Hill Co., New York City	Smith

Elements of Water Bacteriology—5th Ed. ($2.50)	John Wiley & Sons, New York City	Prescott & Winslow
"Industrial Water Supplies" (nominal charge)	Ohio Geological Survey, Columbus, Ohio	C. W. Foulk
pH and Its Practical Application ($3.50	Williams & Wilkins Co., Baltimore, Md.	LaMotte, Kenny & Reed
Elimination of Tastes and Odors in Water ($5.00)	McGraw-Hill Co., New York City	Baylis
Boiler Feedwater Purification ($4.00)	McGraw-Hill Co., New York City	Powell
Chemistry of Water and Sewage Treatment****	Chemical Catalog Company, New York City****	Buswell
Water Borne Typhoid Fever Outbreaks (nominal)	Am. Public Health Bureau	Wolman & Gorman
Textbook of Bacteriology ($8.00)	D. Appleton & Co., New York City	Zinser & Jones
Corrosion; Causes and Prevention ($7.00)	McGraw-Hill Co., New York City	Speller
Water Supply Paper No. 658 (Quality of Waters) (nominal)	U. S. Geological Survey, Washington, D. C.	Stabler
Water Supply Engineering (3rd Ed. $6.00)	McGraw-Hill Co., New York City	Babbitt & Doland
Handbook of Hydraulics ($4.00)	McGraw-Hill Co., New York City	King
Concrete Engineers' Handbook ($6.00)	McGraw-Hill Co., New York City	Hool & Johnson
Pocket Companion (nominal)	Carnegie Steel Corp., New York City	
Business Law for Engineers ($4.00)	McGraw-Hill Co., New York City	Allen
Mechanical Engineers' Handbook—11th Ed. ($5.00)	John Wiley & Sons, New York City	Kent
Elements of Hydraulics ($1.50)	John Wiley & Sons, New York City	Merriman
Guiding Principles of Public Service Regulations (3 Vols.)	Public Utilities Reports, Inc., Rochester, N. Y.	Spurr
Theory and Practice of Public Utility Valuation****	McGraw-Hill Co., New York City****	Maltbie
Public Utility Rates****	McGraw-Hill Co., New York City****	Barker
Public Utility Rate Structures ($4.00)	McGraw-Hill Co., New York City	*Nash*
Census of Munic. Water Purification Plants (nominal)	Am. Water Works Assn., New York City	
Business Administration for Engineers ($5.00)	McGraw-Hill Co., New York City	Harding & Canfield
Census of Municipal Water Purification Plants (50c)	Am. Water Wks. Assn., New York City	
Index to Jour. of A. W. W. A.—1881-1933 ($2.50)	Am. Water Wks. Assn., New York City	

*Revised and enlarged, Apr., 1939.
****Out of print. Try National Bibliophile Service, 347 Fifth Ave., N. Y. City.

For Journals see list No. 1.

LIST NO. 3*—FOR OPERATORS AND MANAGERS OF SMALL SEWAGE WORKS**

Books	*Publishers*	*Authors*
Operation and Control of Sewage Treatment Plants (F)	New York State Dept. Health	N. Y. State Dept. Health
Arithmetic of Sewage Disposal $2.00)	John Wiley & Sons, New York City	Imhoff & Fair
Sewerage and Sewage Disposal Text Book ($6.00)	McGraw-Hill Co., New York City	Metcalf & Eddy
Bulletins Nos. 59, 68, 69, 84 and 86 (F)	Iowa State College, Ames, Iowa	Various
Manual of Sewage Works Operation (nominal)	New Jersey Sewage Expt. Sta., New Brunswick, N. J.	
Reprints of Technical Papers on Chlorine in Sewage Treatment (F)	Wallace & Tiernan Co., Newark, N. J., and The Chlorine Inst., N. Y. C.	
Chlorination in Sewage Treatment (F)	Amer. Pub. Health Assn., N. Y. C.	Committee Reports
Chemical Treatment of Sewage (nominal)	Amer. Pub. Health Assn., N. Y. C.	Committee Report
Standard Methods of Water and Sewage Analysis ($2.50)	Amer. Pub. Health Assn., N. Y. C.	A. W. W. A.-A. P. H. A.
Laboratory Manual of Water and Sewage Analysis ($2.50)	McGraw-Hill Co., New York City	Theroux, Eldridge & Mallman
Sewage Works Journal—(Official publication of the Federation of Sewage Wks. Assns.) Current Sewerage Magazines		
Sewer Rentals ($1.50)	Am. Public Works Assn., Chicago	Various

*Revised and enlarged, Apr., 1939.

LIST NO. 4*—FOR MANAGER, CHEMISTS AND OPERATORS OF LARGE SEWAGE WORKS**

(In addition to List No. 3 for smaller works)

Books	*Publishers*	*Authors*
American Sewage Practice Vol. 3, Sewage Treatment (1935 Edition) ($7.00)	McGraw-Hill Co., New York City	Metcalf & Eddy
Solving Sewage Problems ($6.00)	McGraw-Hill Co., New York City	Fuller & McClintock
Sewerage and Sewage Treatment—4th Ed. ($5.00)	John Wiley & Sons, New York City	Babbitt
The Chemistry of Water and Sewage Treatment****	Chemical Catalog Co., New York****	Buswell
The Hoover Plumbing Code (B. H. 13) (nominal)	U. S. Bureau of Standards	
Sewerage and Sewage Treatment ($3.50)	Intl. Text Book Co., Scranton, Pa.	Hardenberg
Sewerage, 11th Ed. ($4.50)	John Wiley & Sons, New York City	Folwell
Sewage Disposal****	John Wiley and Sons, New York City****	Kinnicutt, Winslow & Pratt
Modern Sewage Disposal ($3.50)	Federation of Sewage Works Assns., New York City	Various
Sewers (25 shillings)	Chapman & Hall, London	Bevan and Rees

(F) Available as Free Publication at this writing, Apr., 1938.
*Revised and enlarged, Apr., 1939.
****Out of print. Try National Bibliophile Service, 347 Fifth Ave., N. Y. City.

Journals and Magazines (*Applies to Lists* 3 *and* 4)

***Note*—Sewerage men should examine Lists 1 and 2—also for several (F) publications of value to all alike—for instance, "Conversion Factors for Engineers" and the hand-books of pipe and pump data.

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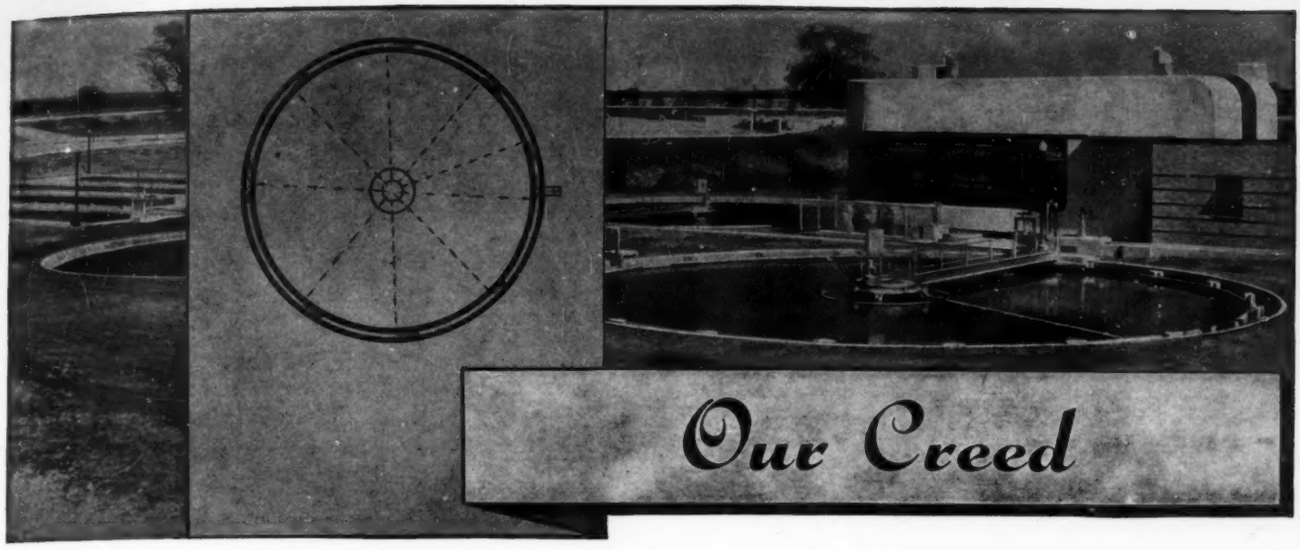


ON SEDIMENTATION FUNDAMENTALS

EASY it is, these busy days, to lose sight of the tree on account of the woods—to forget the acorn that gave life to the oak—to overlook the fundamentals upon which every great and enduring work stands.

In the clash of competition—in the welter of conflicting viewpoints—the trivial and the superficial differences often obliterate the real differences—the fundamental ones.

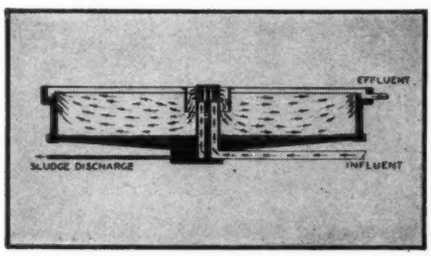
Hence this advertisement. Simply a restatement of what we believe and always have believed on the fundamentals of Sedimentation.

▶ ***FEEDING***—*We believe that Feed should enter at the center—quietly and well below the surface. This, we hold, gives correct diffusion and eliminates short circuiting, eddy currents and variable baffle effects.*

▶ ***DISTRIBUTION***—*We believe that The distribution or diffusion of feed throughout the tank should take place in a radial direction—outward from the center to the periphery. This, we know, causes a gradual deceleration of the flow rate, reaching an irreducable minimum at the point of overflow take off.*

▶ ***OVERFLOW***—*We believe that The overflow weir should be of maximum possible length and at all points equidistant from the point of feed. This, we contend, is best provided by a continuous peripheral weir, which assures the greatest line of flow and the decantation of the shallowest and clearest layer closest to the surface.*

▶ ***SLUDGE REMOVAL*** — *We believe that Sludge should be withdrawn from directly below the point of feed inlet at the rate of deposition. This assures heavy solids settling close to sludge outlet, hence minimum raking distance and minimum period of time in tank. Furthermore, a slowly revolving series of short rakes tends to squeeze out entrained moisture, without lifting or disturbing the sludge blanket.*



We believe this creed of ours. It has been practiced for twenty years and never seriously challenged. Fundamental itself, it jibes with the fundamentals of hydraulics and has sired more than 1000 Dorr Clarifiers, treating more than 4000 M.G.D. of sewage, water and wastes in 40 states and 13 foreign countries.

If this line of reasoning appeals to you as intelligent, you will be interested in our 40 page bulletin on "Sedimentation." May we send you a copy?

DORRCO

The DORR COMPANY Inc.

ENGINEERS • 570 LEXINGTON AVENUE • NEW YORK

ATLANTA • TORONTO • CHICAGO • DENVER • LOS ANGELES

DORR TECHNICAL SERVICES AND EQUIPMENT ARE ALSO AVAILABLE FROM THE FOLLOWING COMPANIES:

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ITALY: S.A.I. Dorr-Oliver, Milan • JAPAN: Sanki Eng. Co., Ltd., Tokyo • SCANDINAVIA: A.B. Hedemora, Hedemora, Sweden • AUSTRALIA: Crossle & Duff Pty. Ltd., Melbourne
ARGENTINA: Luis Fiore, Buenos Aires • SOUTH AFRICA: Edward L. Bateman Pty. Ltd., Johannesburg • BRAZIL: Oscar Taves & Co., Rio de Janeiro

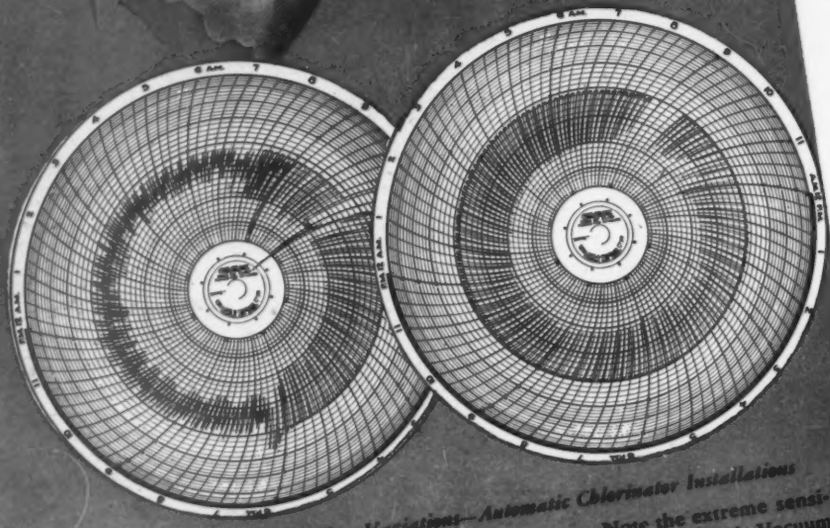
W&T PRESENTS THE CHECK AND DOUBLE CHECK OF CHLORINATION

Graphic indication of chlorine flows for instant verification of chlorinator settings. Permanent chart records for positive evidence of chlorinator performance. Both are now possible with W & T CHLORINE FLOW and CHLORINATION POTENTIAL RECORDERS.

From the simplest "continuity recorder" that registers deviations from correct chlorinator setting to the remote flow indicator, recorder and totalizer—they will be on display at the A.W.W.A. Convention, Atlantic City—June 11 to 15—together with other new W & T developments including the POTENTIAL method of chlorination.

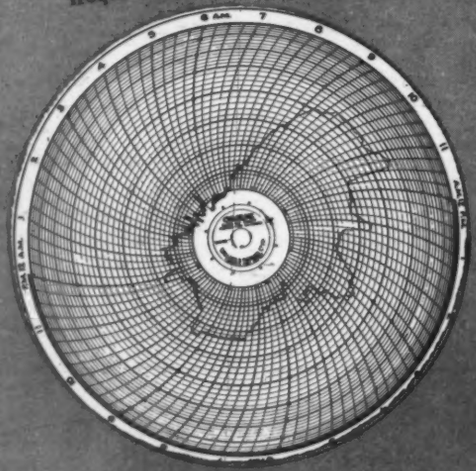
If you can't come to Atlantic City—write for free technical publications illustrating these new indicating, recording devices and their applications.

"The Only Safe Water is a Sterilized Water"



Graphic Recording of Chlorine Flow Variations—Automatic Chlorinator Installations

These charts are taken from actual field operating apparatus. Note the extreme sensitivity with which the recorder follows the changes in flow from W&T Visible Vacuum Automatic Chlorinators installed where fluctuating water flows and pumpage entail frequent automatic adjustment of chlorinator rate of feed.



Graphic Recording of Chlorine Demand Changes

This chart records the amount of chlorine fed to maintain a constant chlorination potential of a supply with changing flows and changing chlorine demands.

WALLACE & TIERNAN CO. INC.

MANUFACTURERS OF CHLORINE AND AMMONIA CONTROL APPARATUS

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